BIOLOGY

A Textbook for Higher Secondary Schools

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Higher Secondary Schools

SECTION 6
Evolution, Heredity and Adaptation

AND

SECTION 7
General

Edited by
P. MAHESHWARI F.R.S.
and
MANOHAR LAL

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Dedicated to the memory of
Professor P. Maheshwari
who completed the work on this
volume but did not live to see the
fruits of his labour in print.

ACKNOWLEDGEMENT

The National Council of Educational Research and Training has undertaken a major programme to prepare model textbooks in various subjects for the school curriculum. For this purpose, the Council has set up a Central Committee for Educational Literature to guide and direct the programme. Panels of specialists have been set up by the Central Committee to develop curricula and to write textbooks, teachers' resource books and other materials on various subjects at school level.

The Biology Textbook Panel worked for two years under the Chairmanship of the late Professor P. Maheshwari, Head of the Department of Botany, Delhi University, to develop the curriculum, syllabus and textbook of Biology for higher secondary classes.

The curriculum and text were reviewed by practising teachers and experts in science education before they were finalised. The first five sections of the textbook namely, 'Some Basic Facts About Life', 'The Diversity of Plant Life', 'The Diversity of Animal Life', 'Plant and Animal Physiology' and 'Self-Perpetuation or Reproduction' have already been published and adopted by the higher secondary schools affiliated to the Central Board of Secondary Education.

The present volume constitutes Sections 6 and 7 of the series and deals with 'Evolution, Heredity and Adaptation' and general topics such as the interdependence of plants and animals, the span of life, human disease, and biology in relation to human welfare.

The National Council wishes to place on record its deep appreciation of the contribution made by the late Professor P. Maheshwari and the members of the Biology panel to the preparation of this volume.

Any suggestions for improvement in this textbook will be gratefully considered by the National Council.

L.S. Chandrakant

New Delhi
January 1967

Foreword

FOR several years I have seriously felt the lack of good school and college textbooks on biology. Most of the existing books emphasize only the descriptive aspects of the subject, largely ignoring the newer and more fundamental concepts. This is, in part at least, responsible for adversely influencing the public image of biology and for relegating it to a subordinate position in the list of sciences. No thinking person can doubt that biology profoundly affects the life of all human beings and its study is one of the most essential requisites of every responsible and intelligent citizen. Further, the study of biology must begin right in the school as an integral part of any course in science instead of being postponed to the college or university stage. The pupil's choice of the subject of his future study is determined, to a large extent, by the courses he has attended in school and by the type of text matter presented to him at this stage.

Recognizing the above facts, I readily accepted the invitation of the National Council of Educational Research and Training to act as Chairman of the Panel set up to prepare a new and modern textbook suited for use in Indian Secondary Schools.

This publication comprises the final—sixth and seventh sections of the textbook. It deals with Evolution, Heredity, Adaptation, and some general topics. In due course, all the seven sections will be produced as a single bound unit.

It may be noted that there are several ways of approaching the subject of biology, each having its own merits and demerits. The editors and members of the Panel are convinced that a wide acquaintance with a number of different kinds of organisms, their activities, their habits and their tissues and organs, is essential and basic to the understanding of the general concepts of evolution, ecology, heredity and cell physiology. This approach, in their opinion, combines not only the pedagogical advantage of proceeding from

the known to the unknown but also prevents students from getting lost in the intricacies of the more advanced aspects of biology.

Although evolution is treated separately in two chapters, an attempt has nevertheless been made to acquaint the student with this all pervasive principle during his study of the world of life. Biological phenomena common to plants and animals have been discussed together as far as possible. Technical terms have been kept down to the minimum except when their use is believed to contribute to easier communication and understanding. Important biological discoveries have been dealt with in a historical perspective to give an idea of how science progresses.

It has been our objective to present the subject in an understandable, stimulating and instructive fashion. We shall appreciate receiving comments, criticisms and suggestions. These will be taken into account in bringing out a revised version of the book.

The original drafts of the chapters in the book were contributed by several persons whose names are given below in alphabetical order: Dr. R.N. Chopra, Reader in Botany, University of Delhi; Mrs E. Gonzalves, Biology Department, St. Xavier's College, Bombay; Prof. N.B. Inamdar, Head of the Department of Zoology, Institute of Science, Bombay; Prof. B.M. Johri, Department of Botany, University of Delhi; Dr. G.N. Johri, School of Studies in Zoology, Vikram University, Ujjain; Dr. L.N. Johri, Reader in Zoology, University of Delhi; Dr. M.S. Kanungo, Reader in Zoology, Banaras Hindu University; Dr. Manohar Lal, Department of Botany, University of Delhi; Dr. S. C. Maheshwari, Reader in Botany, University of Delhi; Dr. L. P. Mall, Reader in Botany, Vikram University, Ujjain; Prof. R.D. Misra, Head of the Department of Botany, Banaras Hindu University; Dr. H. Y. Mohan Ram, Reader in Botany, University of Delhi; Prof. M. R. N. Prasad, Department of Zoology, University of Delhi; Dr. B. Tiagi, Reader in Botany, University of Rajasthan, Jaipur; and Dr. H.S. Vishnoi, Department of Zoology, University of Delhi.

There was naturally a good deal of editing work to be done in order to bring the manuscripts into a form suitable for publication, and to add the illustrations to make the text understandable. In this I was ably assisted by my colleague Dr. Manohar Lal whose help was invaluable in looking after the large volume of work associated with such a project.

I received the ungrudging help of several other persons among whom special mention must be made of Drs. S.P. Bhatnagar, N.N. Bhandari, K.M.M. Dakshni, G.S. Paliwal, Sipra Guha and Man Mohan Johri and Messrs. T.S. Rangan and S.S. Bhojwani of the Botany Department, University of Delhi, who looked after much of the day to day routine and the reading of the proofs. Prof. Ralph Buchsbaum of the Department of Zoology, Univer-

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I must add that the book might never have seen the light of the day but for the constant help and generous co-operation of the following officers of the National Council of Educational Research and Training: Mr Raja Roy Singh, former Joint Director; Mr L.S. Chandrakant, Joint Director; Mr P.N. Natu, Secretary; Dr. R.N. Rai, Head of the Department of Science Education; Mrs S. Doraiswami and Mrs A. Krishnaswami, former Chief Publication Officers; Mr Abul Hasan, Chief Publication Officer, and Mr S. Doraiswami, Secretary of the Biology panel.

P. MAHESHWARI
Chairman, Biology Panel
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Delhi
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P. MAHESHWARI
Chairman, Biology Panel
National Council of Educational Research and Training

Delhi
May 1966

Preface

IN the midst of the present remarkable achievements in rocketry, nuclear energy, synthetic plastics and fibres, and exploration of space, the study of living organisms, their functions and their importance is frequently minimized or overlooked. It is often forgotten that the primary aim of science, apart from the satisfaction of intellectual curiosity, is the survival and welfare of man. Nothing has contributed more to human welfare and to the very emergence of man from his early animal behaviour, than the knowledge of plants, animals, and his own body. It is said that there are four chief ravages of humanity—diseases, wars, famine, and now over-population. From man's point of view, therefore, biology is the most fundamental and important of all the sciences. It affects vital state policies on matters like conservation of natural and human resources, radiation experiments, population control, quarantine and health programmes. Biology also helps us answer such personal questions as: what determines sex; who is responsible for the sex of the baby—the mother or the father; how are twins born; why do babies resemble their parents; how do we acquire immunity against a disease; why do we become enfeebled in old age; how are plants and animals interdependent; and so on. Sanitation, nutrition, pest control, and other attributes of intelligent citizenship—all require a biological background. Finally, biology—a study of the unity as well as the diversity of plant and animal life—is an intellectually enlightening and aesthetically satisfying experience. Indeed, in view of its importance in everyday life, biology should be made a compulsory subject for all school boys and girls. For all this we need adequate textbooks which present the subjects in a satisfactory manner keeping in view the needs of the country for which the book is written. The present book is an attempt in that direction.

Should Botany and Zoology be Taught as Separate Subjects ? The book adopts, in so far as possible, a common treatment of plants and animals and attempts to emphasize the basic unity in the organization and functioning of living matter. This might appear at first sight to be rather undesirable to those who are used to teaching botany and zoology as separate, well-defined subjects with little or no similarity. They might indeed question

the commonness between a cow and a 'neem' tree. To such critics we owe an explanation right in the beginning.

In the nineteenth century there was a tendency towards compartmentalization of subjects but the insight into the life processes acquired in the past 50 years has shown how these compartments merge into each other. Recent work on cell physiology with the newer techniques of biochemistry and biophysics has particularly called attention to a basic commonness between plants and animals. This common ground also extends into the fields of genetics, cytology, evolution, physiology and electron microscopy. There is no reason why at the higher secondary stage the student should not be apprised of these broadening horizons. So far as some other aspects are concerned, the book still retains separate sections on plants and animals. It may be added that in English and American schools a composite biology course has been in use for the last 10 to 15 years, and some universities too have recently begun to offer similar courses at the B.Sc. level.

Even at the research level, many well-known laboratories in the UK and the USA have a common unit for work on both plants and animals. If we are to train the younger generation for successful careers in biological research, it is necessary to orient our school courses in such a way that they get the right perspective of the subject. It may also be pointed out that the school biology course would be the only one which many of our boys and girls will ever attend in their life.

Biology in the Twentieth Century. The nineteenth century biologists concerned themselves mainly with the morphology and anatomy of plants and animals. While this was natural, the subject has undergone much change in its content and character in the twentieth century. This has been made possible largely by the availability of new techniques of chemistry and physics although many milestones have also been laid purely by keen observation and logical analysis. The rediscovery of Mendel's laws of heredity infused new interest into the field of genetics, and the mechanism of inheritance was firmly established. Artificial means of inducing mutations in plants and animals were discovered and the genes responsible for the expression of a particular character were pin-pointed. Electron microscopy, ultracentrifugation, spectrophotometry and other techniques have further unravelled the intricate machinery of the living cell, and these studies have now gone as far as the isolation and artificial synthesis of the hereditary substance—DNA. The study of enzymes, which was a minor discipline in the last century, has grown into a vast area of research. Our knowledge of vitamins, hormones and antibiotics is also a gift of the present century biology. An understanding of the mechanism of nerve action, brain functioning, photosynthesis, respiration and a host of other physiological processes is also derived from the researches of the last 40 years. To this list may be added the still more recent disciplines like virology, radiation and space biology, the cure for cancer and heart diseases, and finally the attempts to synthesize life itself!

Thus, the emphasis has largely shifted from a descriptive and morphological treatment to the functional aspects. It is apparent that if we continue to train our students only in nineteenth century biology, as indeed is being done in most of our schools and colleges, they will find themselves unsuited to the future needs of the scientific world.

The Need For Change. One factor which makes the existing course rather dull is that its contents are mostly or entirely descriptive. We think that the morphological part must still form the basis of biology and has to be done well, but this cannot be the only part, and that physiology, ecology, evolution, the interrelations between plants and animals and the role of biology in human life are subjects that cannot be left out of consideration. A large fund of biological information acquired during the present century finds no mention in most Indian texts which also do not provide any information about the interdependence of plants and animals. Indeed, many of the existing books are as much as 50 years behind current biological thought. It is perhaps true that some aspects of biology, involving a rather intensive knowledge of chemistry and physics, are too advanced and complicated to be understood by the school student. However, recent tests on the learning potential of young students have clearly shown that the general principles of physiology and genetics can be effectively taught provided a simple and popular approach is adopted and there is some demonstration material for illustration. For instance, problems like what happens in photosynthesis, or respiration, or how living organisms respond to external and internal stimuli, elicit greater interest in the minds of students than learning the characters of a family of plants or describing the pectoral girdle of frog. Similarly, on the practical side, the young student will take much greater interest in experimenting on the digestion of starch by an enzyme than in sketching the shapes of leaves and bones. It would be appalling if a school student should get the impression that biology is nothing more than cutting up frogs and collecting hay, or just a system of naming plants and animals in an unfamiliar language.

It is sometimes argued that our textbooks are already encyclopaedic and that it is hardly possible to add more material in view of the time at the disposal of the students. This no doubt poses some difficulty because scientific knowledge is doubling itself every 10 to 15 years. Indeed, the twentieth century has provided far more scientific information than the last 5,000 years. This knowledge must naturally be incorporated into broad biological concepts so as to become a part of our everyday thinking. To do this one has obviously to cut out certain portions. Such facts as are only of an additive nature or matters of unnecessary detail must therefore be pruned, and the dead wood removed here and there. To take a specific instance, a student need not spend too much time in learning the variations in the organization of flowers or vertebrae. Since everything cannot be taught at the school stage, a judicial balance has to be struck between depth and breadth.

Another surprising factor is that in the past the courses in India in this subject have virtually excluded the study of human biology. While the students have been studying in detail the various types of roots and stems as well as the smallest bones of a frog, they remained wholly ignorant of their own body.

The Book. The book has been divided into seven, more or less independent, sections. In the first section the student is introduced to the subject matter of science, particularly biology, and the characteristics of the living matter. A glimpse of the variety of plant and animal life prepares the student for a more detailed study of these forms in the second and third sections. The fourth section treats the main physiological processes in animals and plants in a simple way. The fifth is devoted to a comparative account of the different modes of reproduction in the plant and animal kingdoms. Heredity, evolution and ecology form the sixth section of the book. The epilogue to the book covers topics like interdependence of plants and animals, the span of life, human diseases, and the role of biology in human welfare.

We have much pleasure in presenting this book to the students and teachers of the Higher Secondary Classes. Any suggestions for improvement will be incorporated in the next edition.

Department of Botany,
University of Delhi.

Editors: P. MAHESHWARI
MANOHAR LAL

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SECTION 7

GENERAL

SECTION 6

Evolution, Heredity and Adaptation

CHAPTER 49

Origin of Life

HOW life originated is a very fascinating question in biology. Philosophers, scientists and others have thought about this problem for many centuries. According to some experts on religion, God created life. The Chapter of Genesis in the Bible records that on the first day God made the heaven and the earth. On the second day, He separated the firmament from the waters; on the third, He made the dry land and plants; on the fourth, He made the sun, the moon and the stars; on the fifth, the birds and the fishes; and on the sixth, the land, animals and man (Fig. 49.1).

In the books on Hindu mythology it is held that Brahma is the God of Creation and it is He who created different living beings. Gods, demons, and men are said to have arisen out of Brahma's head; birds from His breast; goats from His mouth; and herbs, roots and fruits from the hairs of His body.

Ancient and Mediaeval Beliefs

The views in the scriptures did not satisfy everybody. Many people thought that living things such as insects, worms and mice could not only be born from things like themselves but could also arise by **spontaneous generation**, out of mud, dung and earth. In ancient Egypt, the view prevailed that the mud of the Nile could give rise to living creatures when warmed by the sun. Frogs, toads, snakes, mice and even crocodiles were believed to arise in this way, and Shakespeare's readers did not raise any serious doubts on such statements. Van Helmont (1577-1644), about whom you have already read, held that human sweat and wheat grains could serve as the life-giving principle. As a method for actually obtaining living organisms he gave the well-known recipe of placing a dirty shirt in a receptacle containing wheat bran. After 21 days the fermentation stopped; and the gases from the shirt and wheat had formed living mice (Fig. 49.2). Van Helmont was greatly pleased to see that these artificially produced mice were of both sexes and exactly like those born from the 'seed' of their parents.

The Experiments of Redi, Spallanzani and Pasteur

The work of the Italian physician Francesco Redi (1621-1697) formed the turning point in this field. Redi decided to test the idea of spontaneous generation, and in 1668 he published the results of his experiment. He took the flesh of four kinds of animals, and cooked it so that nothing could have remained alive in it,

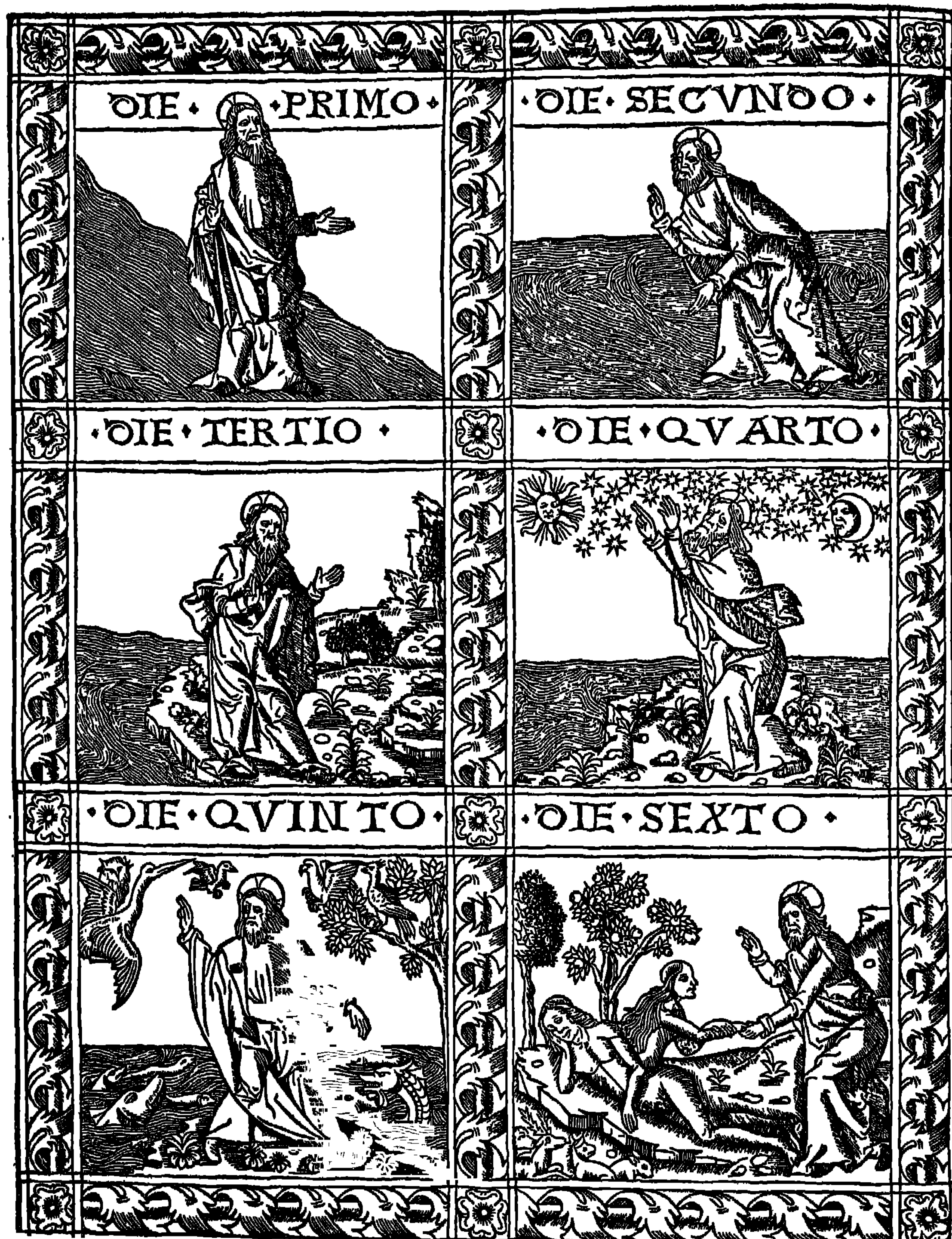


Fig. 49.1. Biblical account of the origin of life as illustrated in a 16th century Bible, printed in Lyons, France.

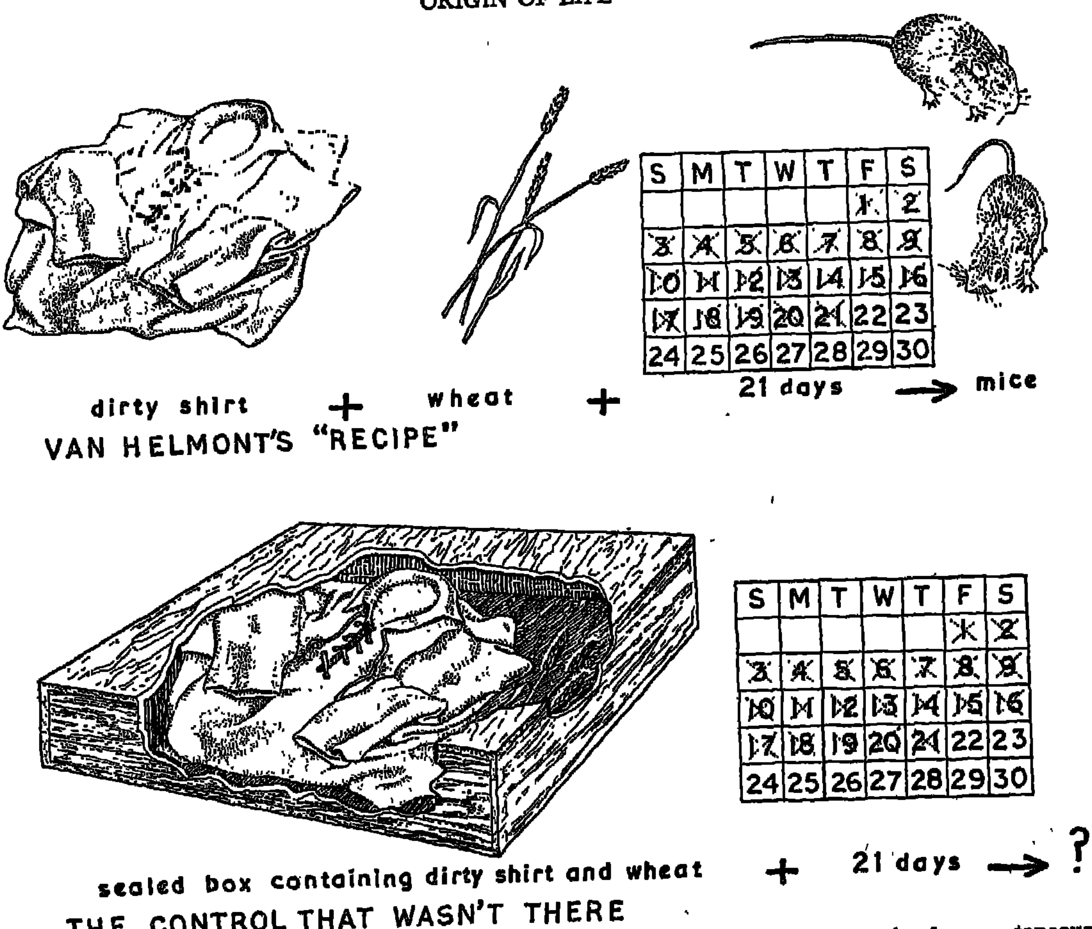


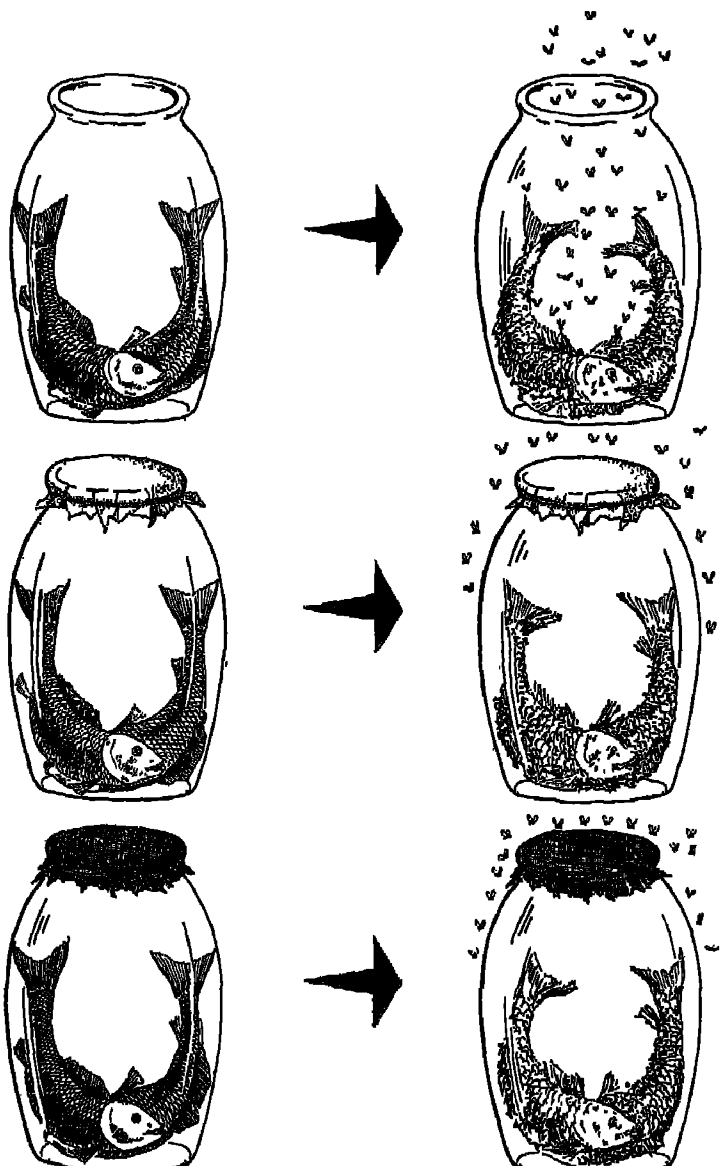
Fig. 49.2. Van Helmont's experiment (with no control) for the production of mice by spontaneous generation. From *BSCS: Biological Science, Molecules to Man,* Houghton Mifflin Company, Boston, 1963.

Then he placed some of each type in three jars. One he left uncovered, the second he covered with parchment and the third with fine muslin. In a few days, maggots appeared in the first jar but none in the second. Although plenty of flies alighted on the muslin covering the third jar, no maggots appeared in the meat (Fig. 49.3). Redi observed how the flies laid their eggs on the muslin, but it was only when these eggs fell on the meat that maggots developed inside it. From this he concluded that the larvae do not generate spontaneously in the meat and that new flies arise only from eggs laid by parent flies.

The Italian scientist and priest, Lazzaro Spallanzani (1765), carried out hundreds of experiments in which decoctions of plant and animal materials were subjected to prolonged boiling, after which the vessels containing them were sealed and thus the access of air to the liquids was prevented. Air, according to Spallanzani, carried the germs or micro-organisms. If the existing organisms in the flasks were killed by boiling and no air admitted, then the liquids contained in the vessel did not putrefy and living creatures did not appear in them.

If any doubts still existed, these were set at rest by the painstaking researches of Pasteur. Tempted by the announcement

of the French Academy of Sciences of a prize to anyone who could throw light on the question of the primary origin of living creatures, Pasteur devised some simple but thoughtful experiments. He half-filled a flask with water containing sugar and powdered yeast, then softened the neck of the flask in a flame and drew it out in the shape



When the fishes were cooked and kept in an open jar, maggots and flies appeared soon.

When the jar was covered with parchment, flies could not be seen inside, although many were present outside.

Generally no flies appeared even if muslin cloth was used, although rarely when an egg dropped down, maggots did appear.

Fig. 49.3. Redi's experiment to disprove the theory of spontaneous generation of life.

of the letter S. The contents of the flask were then boiled. When a strong current of steam issued from the mouth of the side tube, boiling was stopped and the flask was allowed to cool. With this treatment the contents of the flask remained unchanged, although the solution was directly connected through the curved neck with the surrounding atmosphere. This was because all particles of dust, including micro-organisms, were retained in the curved part of the S-shaped tube. When the neck was cut off, micro-organisms soon appeared in the liquid (Fig. 49.5).

Fig. 49.4. Louis Pasteur (1822-1895).

Later attempts to find examples of spontaneous generation of living organisms were in vain. This is quite understandable, for micro-organisms are not just lumps of organic material but have a very delicate and complicated organization. It is impossible to believe that complicated structures of this sort could arise in the course of a short time, right before our eyes, out of structureless solutions of organic substances.

Theory of Spontaneous Generation Again

The ideas of special creation as well as spontaneous generation having been rejected, for a number of years scenitists and philosophers were left without any answer. Many even stopped thinking about the origin of life. In 1821 some people made a bold attempt to 'solve' the tangle by saying that the original forms of life had come from some other planet. However, such a view does not explain anything, but merely banishes the investigation of the question to some conveniently inaccessible corner of the universe.

It is only recently, after much hard thinking, that we have begun to get out of this blind end. The credit for this goes to the Russian biochemist Oparin who argued that the spontaneous generation of the first living organisms might reasonably have taken place if large quantities of organic compounds had been present in the primitive oceans.

The Modern Hypothesis about the Origin of Life

The first step. To understand the theory of spontaneous generation properly, let us start with the birth of the earth itself. This event occurred perhaps some 5,000-6,000 million years ago. It is believed that initially the earth was a ball of hot gases, and vapours of various elements. As cooling proceeded, the different elements sorted themselves out according to their weights. The heavy elements like iron and nickel sank

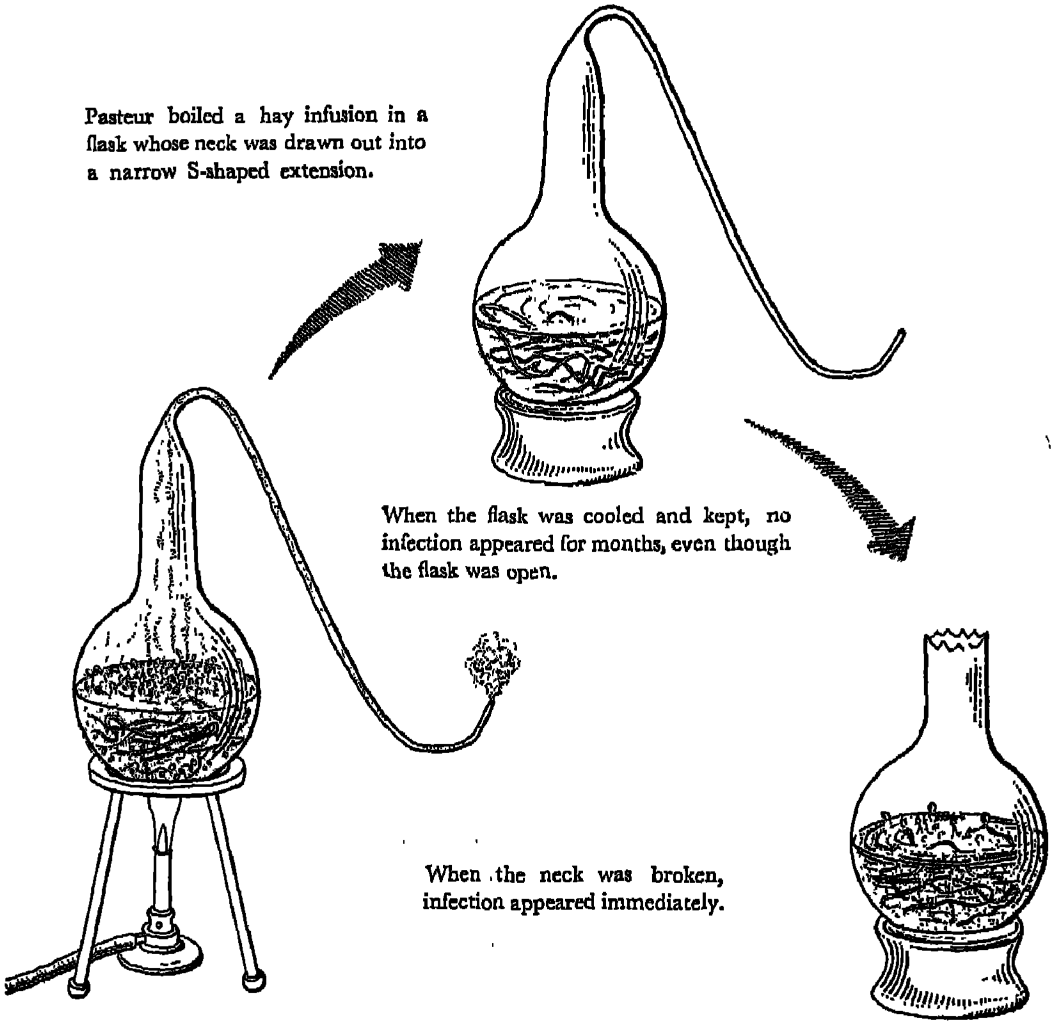
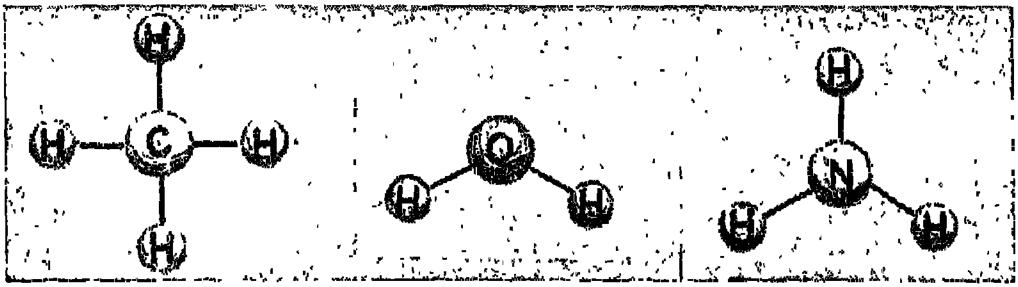


Fig. 49.5. Pasteur's experiment with swan-necked flasks.

to the centre and formed the solid core of the earth. The lighter elements like hydrogen, oxygen, nitrogen and carbon flowed to the surface and formed the gaseous atmosphere. As cooling continued further, molecules began to form by the joining of atoms. Hydrogen being in excess, the three elements were converted into water, methane and ammonia (Fig. 49.6).

As time went on, some of these gases liquefied, and some of the liquids turned into solids. One of the substances that became liquid was water. This resulted in rain. However, the water droplets formed in the atmosphere vapourized as soon as they touched the hot surface of the earth, and returned to the atmosphere. This cycle continued probably for millions of years.



METHANE WATER AMMONIA

Fig. 49.6. The three molecules that constituted the atmosphere of the primitive earth.

But eventually the earth became cool enough to hold water. The torrential downpours flooded the earth, and created rivers, valleys, seas, lakes and oceans. Dissolved in the seas and the oceans were some of the atm spheric ammonia and methane. Rocks also dissolved, leading to an accumulation of salts and minerals in the oceans.

The formation of large bodies of liquid water containing methane, ammonia and many minerals, was the key event which led to the origin of life. Probably the first step itself took about 3,000 million years.

The second step. The principal role in the later history of the earth was played by the gas methane. Because of the unusual bonding properties of carbon, larger compounds such as ethane, propane, ethyl alcohol, glycerol, fatty acids and sugars must have arisen. Occasionally, the carbon at one end of such a chain could combine with the carbon at the other end, producing ring-chain type of compounds like benzene. Ammonia too played an increasingly important role so that many nitrogenous compounds such as amino acids were evolved.

In short, many different kinds of molecules were formed (Fig. 49.7). Some of these were made of carbon, hydrogen and oxygen, and others of these elements and nitrogen. Of these, some were straight-chained, and others ring-chained.

The third step. Thus, the primitive earth had the seas full of sugars, alcohols, amino acids and several other kinds of molecules. It was a kind of hot soup in which the atoms continuously collided with each other forming newer and more complex combinations (Fig. 49.8). Many of these were unstable while others were more stable. Probably ultraviolet rays, lightning and electricity provided the energy required to keep these reactions going.

The next stage in the evolution of life was the formation of larger molecules. For example, glucose molecules joined together to give rise to starch while amino acids combined to form proteins. The development of proteins can be considered a landmark because some of these molecules were the enzymes.

An important event in the creation of life seems to be the formation of a nucleic acid molecule from phosphorus, sugars and cyclic carbon-nitrogen compounds. The nucleic acid then combined with proteins to f rm nucleoproteins—giant molecules that form viruses and genes.

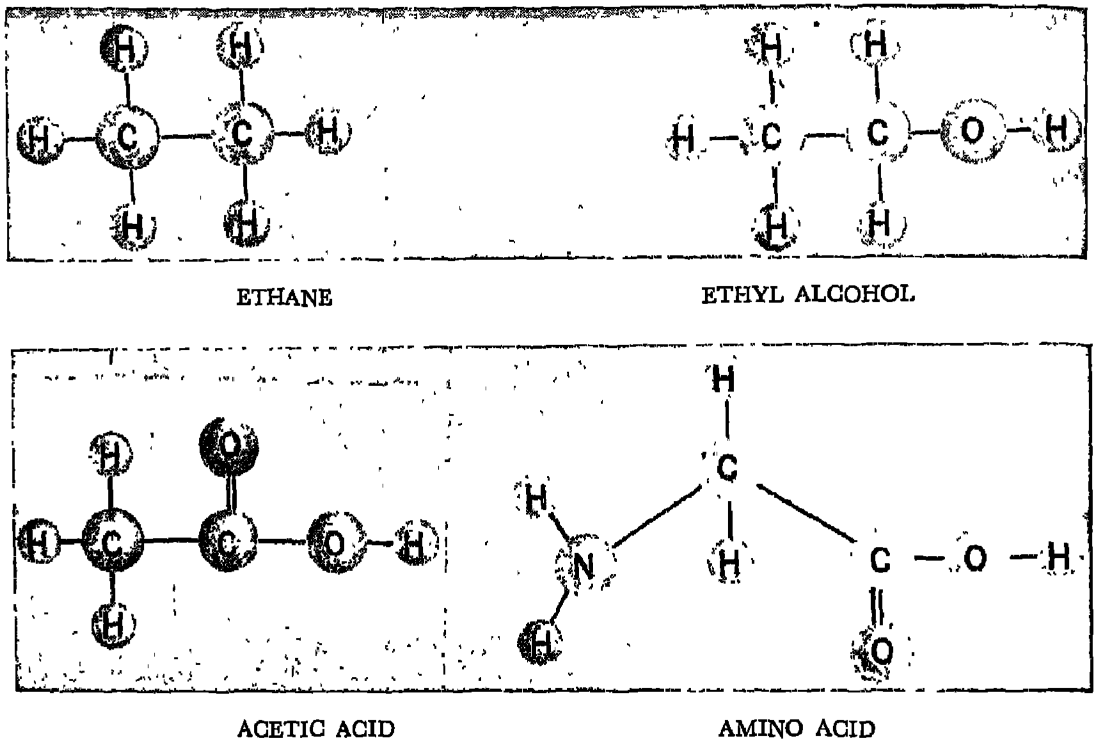


Fig. 49.7. Some of the types of molecules formed during the second step in the origin of Life.

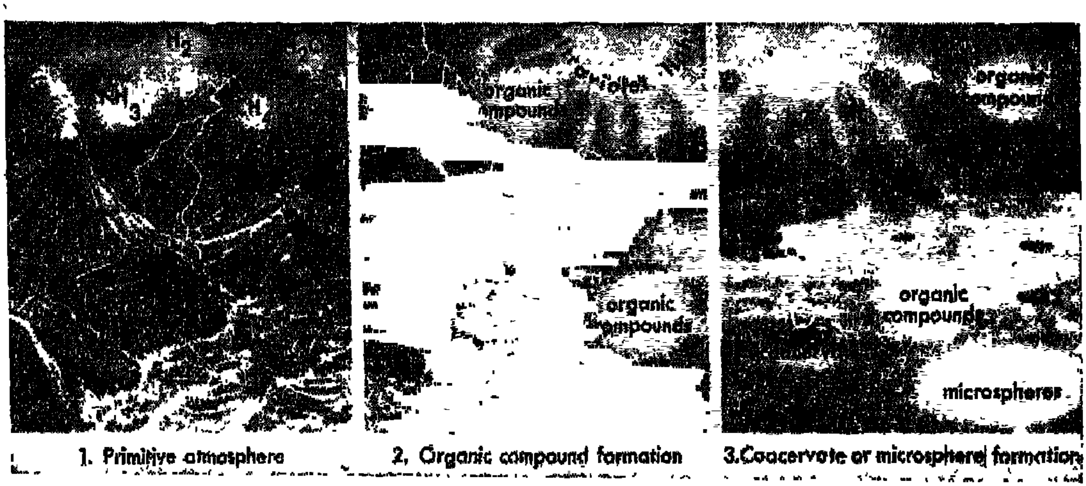


Fig. 49.8. A sequence of events that might have led to the formation of coacervates. From *BSCS, Biological Science: Molecules to Man*, Houghton Mifflin Company, Boston, 1963.

The final step. Granted that sugar, amino acid, fat, protein and nucleic acid molecules came into existence by random collisions between atoms of various kinds, the next and the most difficult step was the creation of a cell. How the cell membrane arose, and how it enclosed the various molecules are problems yet to be solved.

Whatever be the mechanism of the origin of the cell, it is clear that the first cell did not have any organized structure like a nucleus. Even today no definite nucleus is found in bacteria and blue-green algae.

Can Man Create Life ?

Before we go any further, we may pause and see if the hypothetical steps outlined so far are merely a product of imagination or can be supported by experimental data gathered by scientists in the laboratory. There are several indications that the earth did pass through the steps outlined above. We discussed, for example, that the primitive earth must have contained a strongly reducing atmosphere consisting of methane, ammonia and water. Presumably Jupiter, Saturn, Uranus, etc., had a similar mode of origin as the Earth itself. Spectroscopic evidence indicates that methane and ammonia do occur in these planets in a permanently frozen state since these planets are far off from the Sun.

Mention must be made here of the experiments of Stanley Miller in America and more recently of Gerhard Schramm in Germany. By subjecting mixtures of ammonia, hydrogen and water to heat and electrical discharge (Fig. 49.10) these scientists have been able to duplicate many of the steps outlined above. Not only various kinds of amino acids and sugars, but even molecules similar to proteins and nucleic acids have been made.

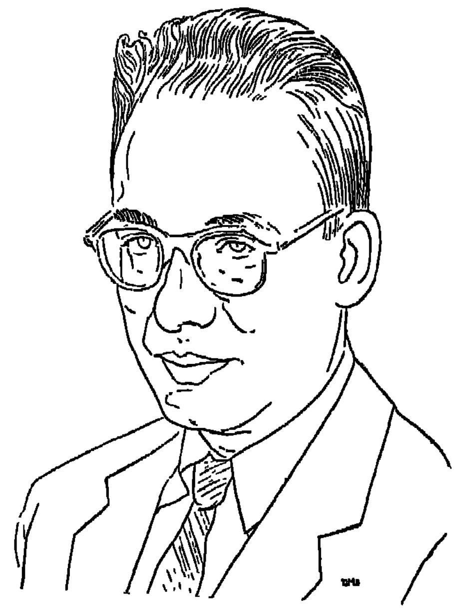


Fig. 49 9. Stanley Miller (1930-).

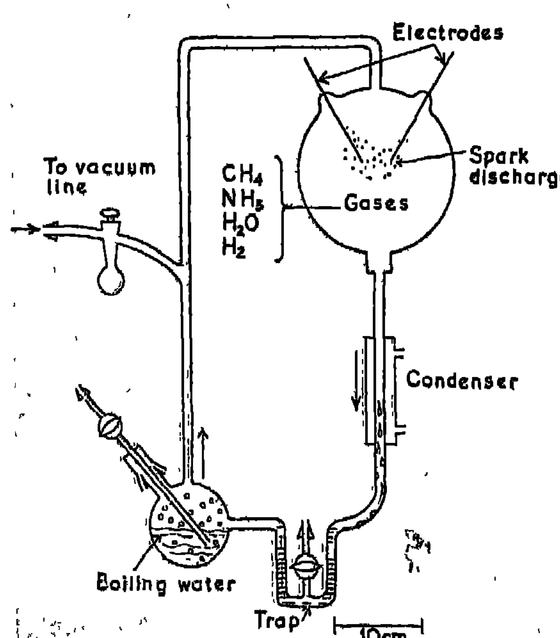


Fig. 49.10. The apparatus used by Stanley Miller to demonstrate the synthesis of amino acids under conditions that existed in the primitive earth (Courtesy of Stanley Miller).

Under certain conditions, scientists have even obtained in the test tube structures that look like cells (Fig. 49.11). These have membranes and seem to grow and reproduce. However, the complex organization of true cells (as seen through an electron microscope) is absent, and they are instead referred to as **coacervates** or **microspheres.**

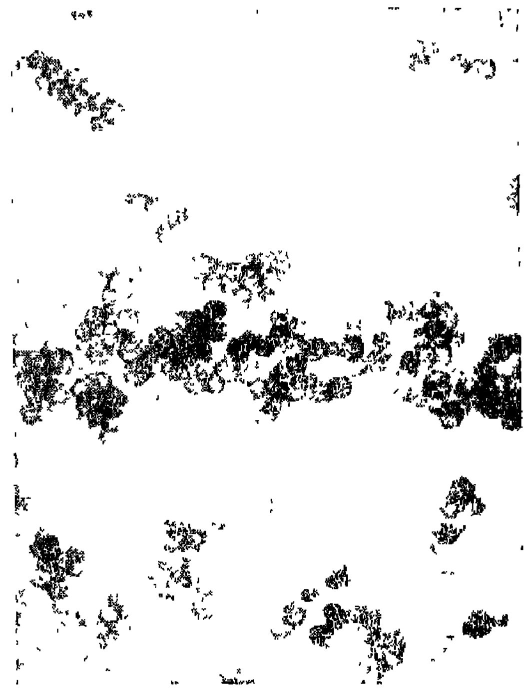


Fig. 49.11. 'Microspheres'—artificial cells produced by heating amino acid solutions (Courtesy of Sidney Fox).

Which Came First, the Animal or the Plant Cell ?

Although the origin of cell is itself not clear, many biologists have wondered whether the animal cell came first or the plant cell. It appears that the primitive cell obtained its energy solely from fermentation, since there was not much free oxygen. Thus some of the food in the cell was broken down to provide energy for the conversion of another portion of the food into more complex molecules.

In course of time the sugars and amino acids, which helped in forming the first cell, became scarce, whereas carbon dioxide became abundant in the atmosphere. Presumably it is at this time that the chlorophyll molecule arose, enabling some of the cells to manufacture their own organic material from carbon dioxide and water. This would result in the presence of both green and non-green cells that have produced the great variety of plants and animals that we see today.

Does Life Exist on Other Planets ?

If spontaneous generation of life has taken place on our Earth, the question arises whether this could have occurred on other planets too. Most of the planets of the solar system have temperatures too high or too low to support life. For example, the temperature on the surface of Mercury, the planet closest to Sun, can reach as high as 400C whereas on the surface of Neptune it may be as low as—200C. Moreover, some of the planets have no atmosphere. Besides Earth, Mars is the only other planet where life could be supported. The temperatures on the surface of Mars range between 60 C and 30 C during day time, and the atmosphere contains carbon dioxide, oxygen and water vapour. Some astronomers have also noted a strange seasonal change in the colour of Mars from bluish green in spring to yellow or brown during autumn. This has been interpreted to mean that chlorophyllous organisms exist on the surface of Mars; they either perish or lose their chlorophyll in the autumn.

While Mars is perhaps the only planet close to us where living organisms may exist, there could be many other planets outside our solar system which support life. Among the stars Sun is only second-rate in size and brightness, and only one of a hundred billion in the local galaxy. Many of these suns have their own planetary systems like ours. Allowing for the fact that many of the planets might be too hot or too cold, too small or too large, with or without atmospheres we are still left with a large number (scientists estimate it as about 10^9) of planets that could support life, and probably do so. Surely, one of the most marvellous feats of the twentieth century science would be the firm proof that life exists on another planet.

SUMMARY

Living things are quite familiar to everyone, but how life began has puzzled man for centuries. Until recently man believed that life either came from other planets, or was created by God, or arose spontaneously from non-living matter.

Scientists today think that life may have arisen from non-living matter. This, however, did not occur overnight or in the course of a few weeks as was believed in the Middle Ages. It must have taken place over a long span of time, billions of years ago.

The atmosphere of the primitive earth may have consisted of methane, ammonia and water vapour. As the earth cooled, molecules of water liquefied to form oceans in which the other molecules dissolved. Later, these molecules reacted with each other to form sugars, organic acids, proteins and nucleic acids. The critical stage was reached when there was formation of virus-like nucleoprotein molecules which had the property of self-duplication. It seems that by aggregation of food around itself, the nucleoprotein molecule became a cell, and still later the cell gave rise to the multi-cellular organism.

Man has been able to duplicate a few steps of this process in the laboratory, but even today he has not succeeded in making a cell, much less a complicated plant or animal. Meanwhile, research continues hopefully, and one day he will be able to create life.

QUESTIONS

1. What is meant by 'spontaneous generation' of life? Who proposed this theory and who refuted it?
2. What is the difference, if any, between the present view on the origin of life and the theory of spontaneous generation?

3. What, in your opinion, is the basic characteristic of life?

4. Match the contributions in the column on the right with the appropriate scientists on the left.

Van Helmont	Overthrow of the theory of spontaneous generation and experiments with swan-necked flasks. (2)	Pasteur	Artificial synthesis of amino acids, the essential constituents of life. (3)
Miller	Experiments with pieces of meat in bottles kept uncovered and covered. (4)	Spallanzani	Recipe for the spontaneous generation of life—placing a dirty shirt in bran of wheat. (1)

FURTHER READING

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CHAPTER 50

Heredity and Variation

At one time or the other you may have pondered over such questions as: Why do hen's eggs always hatch into chicken and not sparrows? Why do children in a family resemble one another but are not exactly alike? Why do they only partly resemble their parents? How do black-eyed parents sometimes have a brown-eyed child? How is it that an idiotic child is sometimes born to parents who are perfectly normal? How may the son of an illiterate farmer sometimes come up to the status of the President of a country, while a boy from a royal family with the best possible facilities may put up just ordinary performance? What have X-rays and other atomic radiations to do with the welfare of human race? Does tuberculosis run in families? The answers to these and many more similar questions come from an important branch of biology, called **genetics.** There are two main components of this discipline. The first is **heredity** or the study of the factors responsible for the resemblance between the parents and their offspring. The second, called **variation**, is concerned with the forces or influences due to which no two organisms are exactly alike.

Like Begets Like—Heredity

Let us begin by understanding the meaning of the famous saying 'like begets like'. In biology it simply means that living things always produce their own kind. Thus a mango tree eventually produces more mango trees, elephants produce baby elephants, and bacteria divide to form more bacteria. What makes this possible? Well, you have already learnt that most organisms start their life as a single cell, the zygote, which is formed by the union of a sperm and an egg. By repeated divisions and differentiation a zygote grows into a particular kind of organism. The zygote 'knows', as it were, whether it is to develop into a cow, a dog, a man or a mango tree. In other words, it has the 'key' to all the processes which will ultimately result in the birth of a particular organism.

Gametes are, then, the only bridge that connects the parents and the offspring. And can you fancy that in these microscopic gametes must be packed all the parental characteristics such as the stature of the body; the shape of the nose; the colour of the eyes; the type of hair, skin and blood; and a host of other things that characterize you as You! Of course the actual characteristics such as the flat nose or the curly hair cannot be found in the gametes, but something representing these, and having the ability of producing these characteristics in the new organism, must be present. The hereditary bridge can be further localized

to the nucleus of the gamete. Just have a fresh look at figure 48.6, and recall the process of gametic fusion (fertilization) in plants and animals. The eggs of most organisms contain nucleus and some cytoplasm. The sperms consist of nucleus and a little or sometimes no cytoplasm. Moreover, nothing more than the sperm nucleus enters the egg during fertilization. Add to this the common observation that in bisexual individuals the offspring possesses the same characters no matter from which of the two parents the eggs and sperms are derived. In other words, each of the two gametes makes an equal contribution. Since the only common structure is the nucleus, it is logical to conclude that this is the structure concerned with heredity.

From the scientific work of a large number of biologists over the past 100 years it has been further brought out that the nucleus in every cell of an organism carries a fixed number of chromosomes. The chromosomes contain tiny units called **genes** which actually determine or control the hereditary characters. It is also known that most of our traits such as skin colour, intelligence, temperament, blood types, etc., are determined by genes. Since gametes are the only link between the parents and the offspring, it is certain that the genes for nearly all the traits must be packed into the gametic nuclei. Thus the nucleus of each cell of the human body carries some 20,000 genes, approximately 10,000 having been contributed by each parent. Just try to imagine 20,000 genes distributed lengthwise over 46 chromosomes, all of which are rolled up in a nucleus often no bigger than 0.01mm! Genes are, therefore, infinitely small, so small indeed that no one has yet seen them under even the best microscopes. However, this should not make you doubt their existence. The evidence for their presence is as strong as that for the existence of atoms which too are invisible. The nature of genes will be considered in greater detail a little later.

Variations

Since the offspring contains genes from both the parents, it partly resembles both of them, but the resemblance is never exact. It must have been your own experience that no two individuals of a species, say man, monkey, horse, or dog are exactly alike. What causes these differences or variations? If you recall how randomly the chromosomes are distributed during gamete formation, and how randomly they are re-united at fertilization, you will immediately come to see that the possibility of the children of the same parents being exactly similar to one another is very remote. Thus, a diploid cell carrying two pairs of chromosomes may form gametes with four possible combinations of paternal and maternal chromosomes (Fig. 50.1 A). If the diploid cell carries four pairs, it may form 16 types of gametes containing four chromosomes each (Fig. 50 I B). In human beings each cell has 23 pairs of chromosomes, and the number of possible chromosomal combinations in the gametes is 2^{23} or 8,388,608! This explains why children almost never bear an exact resemblance to their parents.

This shuffling and recombination of chromosomes in sexual reproduction is one of the major causes of variation in the species. Variations may also arise due to environmental factors such as food, soil, water, temperature, light and several others. A third cause of variation is the change or mutation in the genic material itself. This may be caused by several factors, the chief among which is the atomic radiation. We shall consider some of these aspects later in this chapter.

Historical

It may perhaps surprise you to know that the simple mechanism of the transmission of

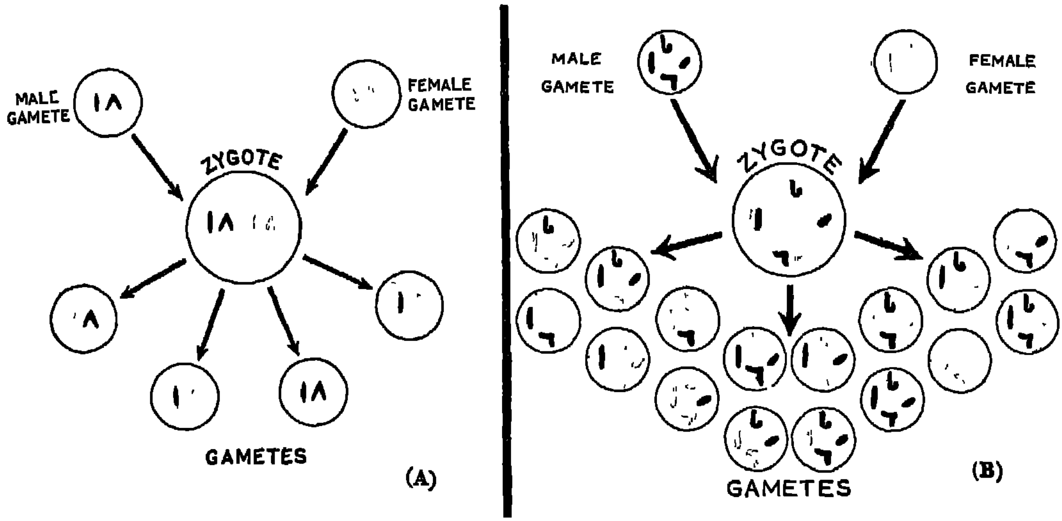


Fig. 50.1. Types of gametes that can be formed from diploid cells having two (A) and four (B) pairs of chromosomes. After C.P. Swanson, *The Cell:* Foundations of Modern Biology Series, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1958.

hereditary characters outlined above was not known till as late as 1900. Indeed, there have been some very funny notions about how hereditary characters are transmitted to the offspring. From the dawn of civilization man has had a vague feeling that good offspring comes usually from good parents. For instance, even an illiterate farmer knows from experience that in order to get cows with high yield of milk, he must breed them from cows and bulls whose mothers were known to give most milk. Similarly, to obtain a bumper crop of grains, he selects the seeds from the most vigorous plants. Although such practices appear logical, they do not always yield the expected results. Sometimes the desired characters do not appear in one or two generations and then reappear in the subsequent generations. This was very puzzling. Regarding the mode of transmission of characters it was thought that in animals and in man the characters were transmitted to the offspring through the blood. The spermatic fluid of man was thought of as highly purified blood which mixed with the mother's blood at the time of conception. Once mixed, the two bloods formed a continuous stream. The mixed blood, and hence a mixture of characters, was in turn transmitted to the subsequent generations. The belief in blending of characters was so widespread that very fanciful explanations were given to explain certain characters of animals. Thus the giraffes, which have spotted skin and long necks, were supposed to have come from the 'marriage' between a camel and a leopard! With the discovery of the microscope in 1676 it became possible to see things which the human eye could not see previously. By 1831 it had been established that all plants and animals are made up of cells and each cell contains a very important structure, the nucleus. Nearly 30 years later it was demonstrated that the nucleus was made of a special substance, the chromatin, which showed up clearly when the cell was coloured with certain dyes.

The next important advance was made around 1880. The chromatin was shown to transform itself at certain stages into thread-like bodies which we now recognize as chromosomes. About the same time came the discovery of mitosis, and it was shown that all the cells of a given species carry a fixed number of chromosomes which pass unchanged from the parents to the offspring. Not only that, the number of chromosomes in the gametes was shown to be half that in the other cells. This revealed that each parent contributed half the total number of chromosomes present in the zygote. Hand in hand with these cytological discoveries came other discoveries in the related field of genetics (Fig. 50.2). Microscopists observed that the semen or spermatic fluid was not purified blood but a solution carrying millions of 'animalcules' or sperms. It took many more years to demonstrate the actual entry of a sperm into a mammalian egg and the details of fertilization.

Mendel and his experiments. The first person to reveal the secrets of inheritance was Gregor Mendel, a monk at the monastery in Brünn, a place in Czechoslovakia. He obtained many varieties of peas and grew them in his garden. There were peas with red flowers and others with white flowers; some were tall (2 m and above) and others short ($\frac{1}{4}$ to $\frac{1}{2}$ m); some had smooth seed coats and others wrinkled seed coats, and so on. He further noted that the seeds from tall plants produced only tall plants; those from dwarf plants, only dwarfs (Fig.

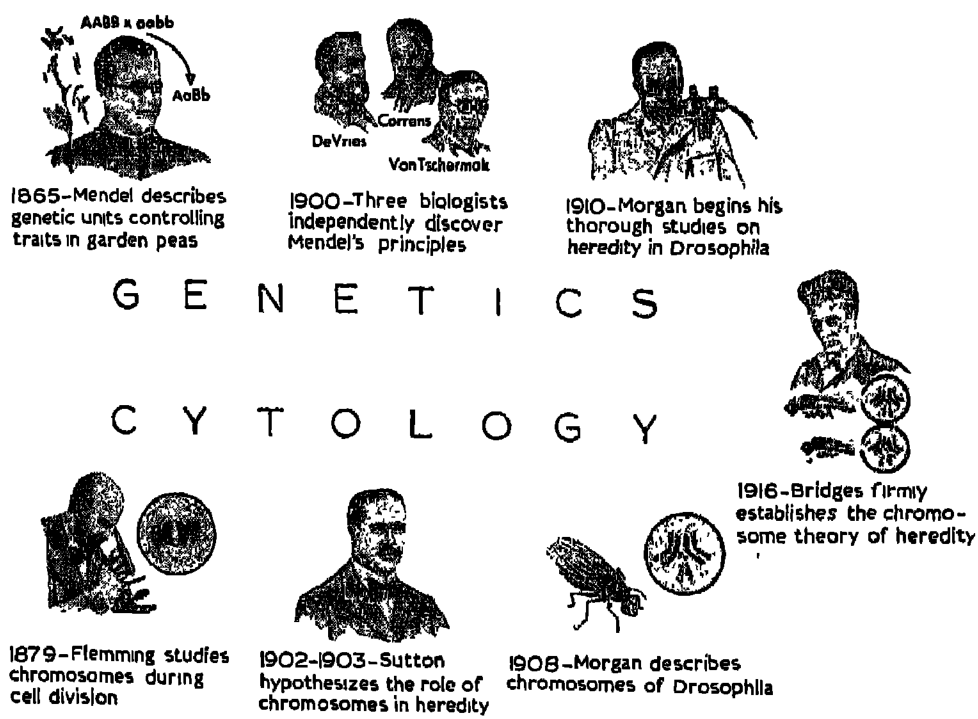


Fig 50.2. Some pioneers and their chief contributions in the fields of genetics and cytology. From BSCS, *Biological Science; Molecules to Man*, Houghton Mifflin Company, Boston, 1963.

50.3). The same was true of the other varieties. In biological terms we would say that these plants **bred true**.

If you have had a chance to observe the pea flowers closely, you would immediately guess why the peas breed true. The pea flower has the shape of a butterfly. Two of the five petals form a boat-like structure and enclose the reproductive organs. Nine out of ten stamens form a tube around the solitary pistil in the centre. Normally the 'boat' remains closed, and self-pollination is the rule.

Mendel wondered what would happen if he artificially **hybridized** (crossed) two distinct varieties such as the dwarf and the tall. He was inclined to guess that the resulting plants would be of an intermediate height. Like a true scientist, however, he proceeded to test this experimentally. He planned and conducted a series of experiments. The conclusions derived from these became the first-ever laws of heredity. Mendel's discoveries rank among the most important scientific achievements. But Mendel died long before the results of his experiments were recognized as the basis of a new science—genetics. The importance of his work was discovered only in the year 1900—16 years after his death (in 1884). You will now read about a few of his experiments, his explanation and laws.

Mendel crossed tall plants with dwarfs. How do you think he did that? First he removed the stamens from a large number of flowers on tall as well as dwarf plants before the pollen was ripe. This kept out any chance of self-pollination. Next, he dusted the stigmas of flowers of tall plants with the pollen from the dwarf plants, and the stigmas of dwarf plants with pollen from the tall plants. In other words, he made 2-way or **reciprocal crosses** in which both the varieties got a chance to act as the male

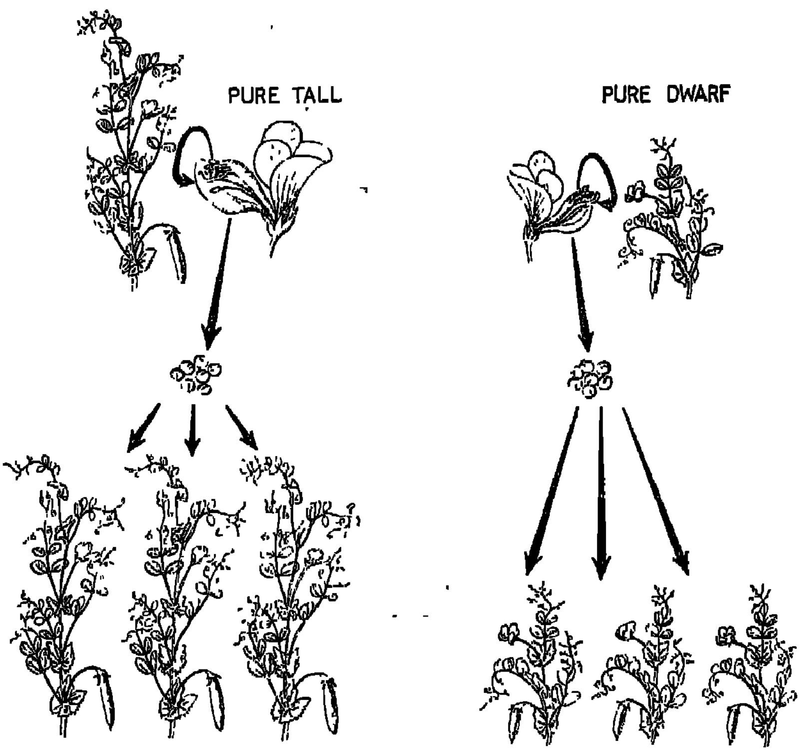
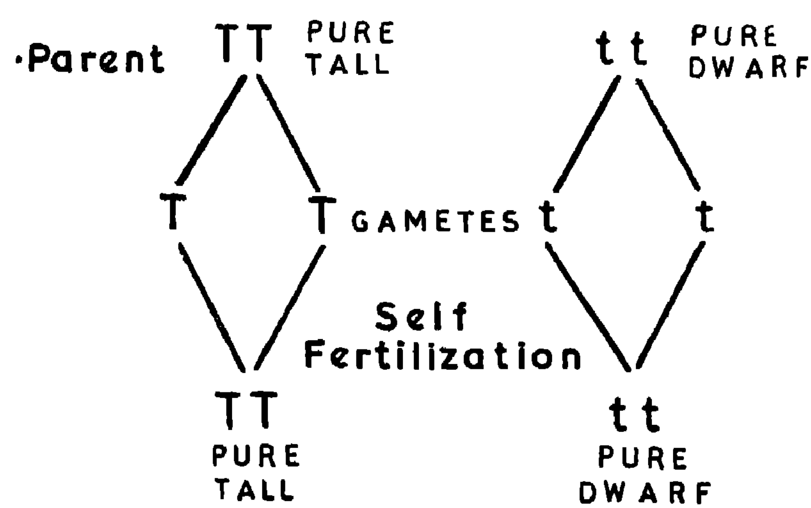


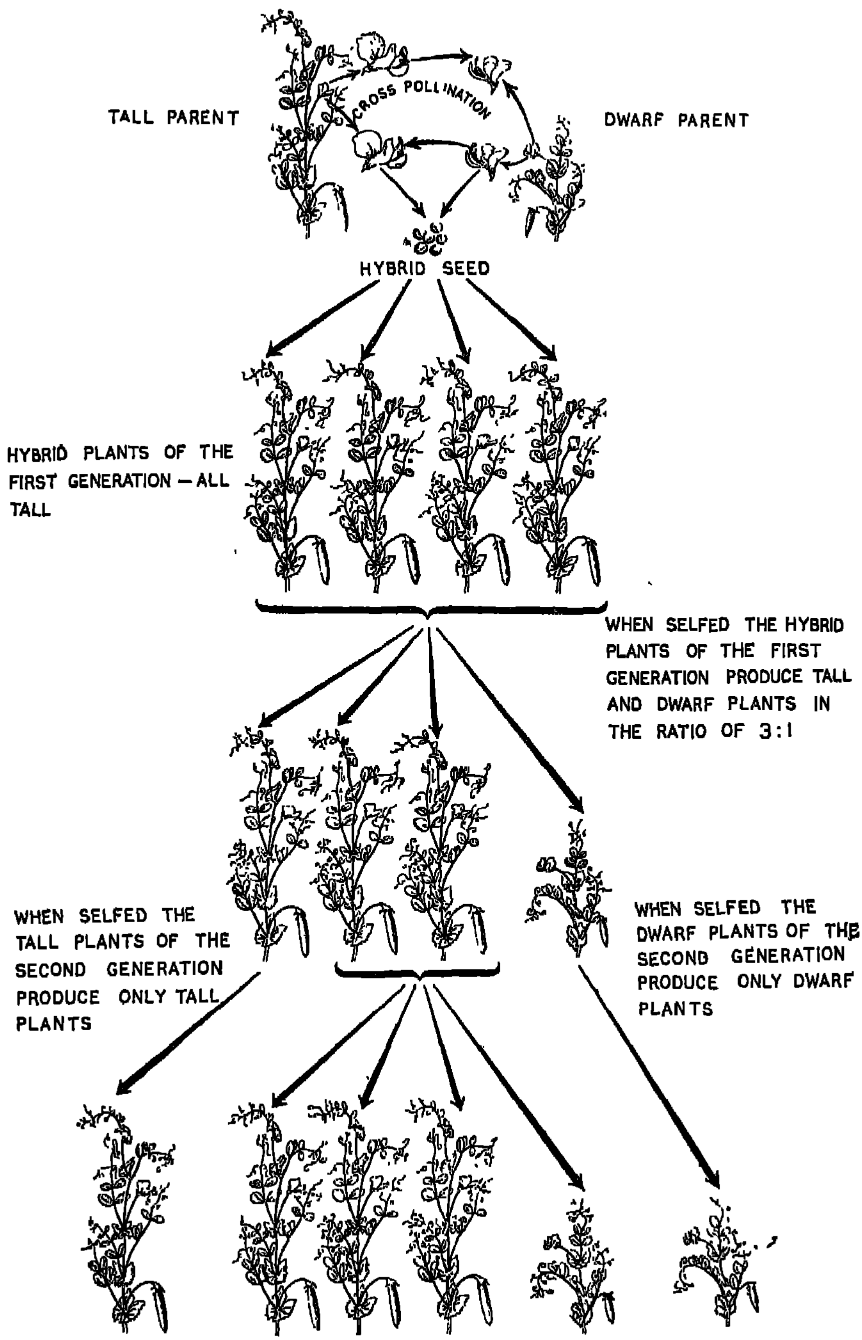
Fig. 50.3. Self-fertilization or inbreeding of pure tall and pure dwarf plants of pea (*Pisum satwum*). The progeny of the tall plants consists of all tall individuals; that of dwarf plants, all dwraf individuals. Courtesy of the Department of Botany, University of Delhi.

or the female parent. He put small labels around his 'experimental flowers', and when the fruits were mature he collected the seeds and kept them in labelled packets. In the following season he sowed these seeds to see what type of plants would result from them. And imagine Mendel's surprise when he saw that all the plants in his 'experimental plot' were tall. There was not a single dwarf, nor a plant of intermediate height. Was the dwarf character somehow lost during its passage from parents to offspring? Mendel had no ready answer to that, but he continued his experiment. This time he did not do any cross-mating. Instead, he allowed the plants (offspring) to self-pollinate, and collected the seeds. When he grew plants from these seeds in the following season, Mendel had another surprise. The dwarf plants had made their appearance once again ! 'How come?', he said to himself, and proceeded to analyse his results. It was a part of his experimental procedure to record his results mathematically and faithfully. He recorded that there was one dwarf plant for every three tall plants. He collected the seeds from every plant into a separate packet and obtained the third generation of plants in the subsequent year. This time still more curious results presented themselves. The seeds from the dwarf plants bred true to their kind, i.e., they produced only dwarfs. The seeds from some of the tall plants also bred true with respect to tallness, whereas the seeds from other tall plants again produced tall and dwarf plants in a 3:1 ratio. The summary of his results is presented in figure 50.4. Mendel then proceeded to find an explanation of his curious results. With his clear thinking he arrived at some important conclusions.

He argued that every character of the pea plant must be determined, or controlled, by a pair of **factors.** When the plant forms gametes, the two factors separate out or segregate, one of each pair going into each gamete. When the gametes unite at fertilization, the two factors again come together. Although he got only tall plants by crossing tall and dwarf plants, he rightly thought that the factor for dwarfness was neither lost nor mixed up, it was only unable to express itself in the presence of the factor for tallness. He stated that the factor for tallness masked, or dominated over, the factor for dwarfness which was **recessive.** He symbolized the **dominant factors** with capital letters and the recessive ones with small letters of the alphabet. Thus, the various factors of the plants shown in figure 50.3 can be symbolized as follows:

When the tall and dwarf plants are bred together, only the tall plants come up in the first generation. They do carry within

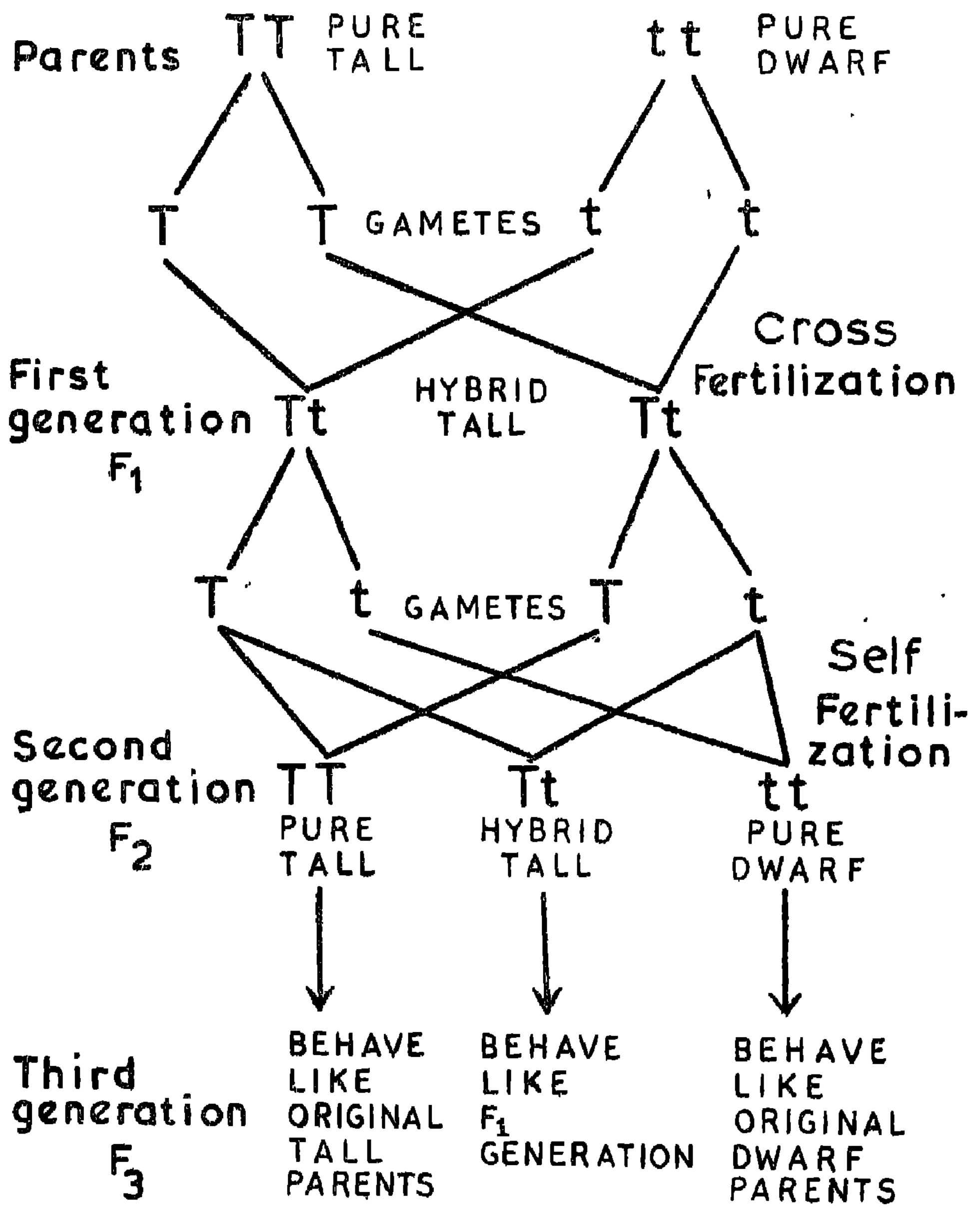




ig. 50.4. **Diagrammatic representation of Mendel's results obtained by crossing tall plants with dwarfs.** Courtesy of the Department of Botany, University of Delhi.

them the factor for dwarfness, but this is not able to express itself. When gametes are formed, the dominant and recessive factors segregate and enter different gametes. By a chance union of gametes both tall and dwarf plants appear in the progeny. Thus the genetic constitution of the various types of plants of figure 50.5 can be symbolized in terms of factors as follows:

A plant in which a dominant factor is paired with a recessive factor is called a **hybrid**, whereas one in which both the



factors are similar, i.e., either dominant or recessive, is known as **pure.** You would also have noted that the plants which are alike in general appearance do not necessarily have the same genetic factors. Thus, tall plants may be either **TT** or **Tt.**

Mendel carried out similar experiments on six other varieties of pea showing contrasting characters such as red and white flowers, smooth and wrinkled seed coats, and so on. In every case he found that the basic pattern of inheritance was the same as that recorded for tall and dwarf varieties. Mendel conducted some more experiments in which he considered two or three factors at a time. After nearly 10 years of hard and systematic work, Mendel formulated the following principles:

1. **Principle of dominance.** Only one of the members of a pair of contrasting characters exhibits itself while the other remains hidden.

2. **Principle of segregation.** The two members of a pair of factors separate during the formation of the gametes. In other words, the contrasting factors do not blend with or contaminate each other, but segregate and pass into different gametes. This principle is also known as the **principle of purity of gametes.**

3. **Principle of independent assortment.** When two individuals differ from each other in two or more pairs of factors, the inheritance of one pair is quite independent of the inheritance of others.

Thus, contrary to earlier beliefs, Mendel suggested that the hereditary characters do not form a mixed stream but are carried in independent units which remain separate. They do not blend with each other.

Although Mendel published his results in 1865, very few people paid any attention to them. In the year 1900 three biologists—Hugo De Vries from Holland, Karl Correns from Germany, and Eric von Tschermak from Austria—independently recognized and announced that Mendel's experiments had laid the foundation of heredity. Many teams of biologists were at that time busy conducting breeding experiments in plants and animals. It was found that Mendel's principles applied not only to peas but also to many other plants and to animals.

Inheritance in Man

We shall now consider some aspects of genetics with respect to ourselves, in an attempt to answering some of the questions raised in the beginning of this chapter.

Will it be a boy or a girl? The birth of a boy or a girl is dependent neither upon favourable stars nor upon the health or age of the parents. It is determined by just two out of 46 chromosomes found in every human cell. Figure 50.5 illustrates how it all comes about. Out of 23 chromosome pairs in the cells of man 22 are normal, i.e. the two members of each pair are alike in size and appearance. In the 23rd pair, however, one chromosome (called **X-chromosome**) is bigger than the other (called **Y-chromosome**). This pair determines sex, and therefore the X and Y chromosomes are called the **sex chromosomes.** In a woman both the sex chromosomes are similar and are designated XX. During gamete formation, the two sex chromosomes enter different gametes (sperms and eggs). Thus, the male (XY) produces two types of sperms—those carrying X+22 chromosomes and those with Y+22 chromosomes. The female produces only one type of eggs—all with X+22 chromosomes. If an X+22 sperm fertilizes the egg, a female baby is born. If a Y+22 sperm effects fertilization, a male baby is initiated. Man releases millions of sperms of both the types

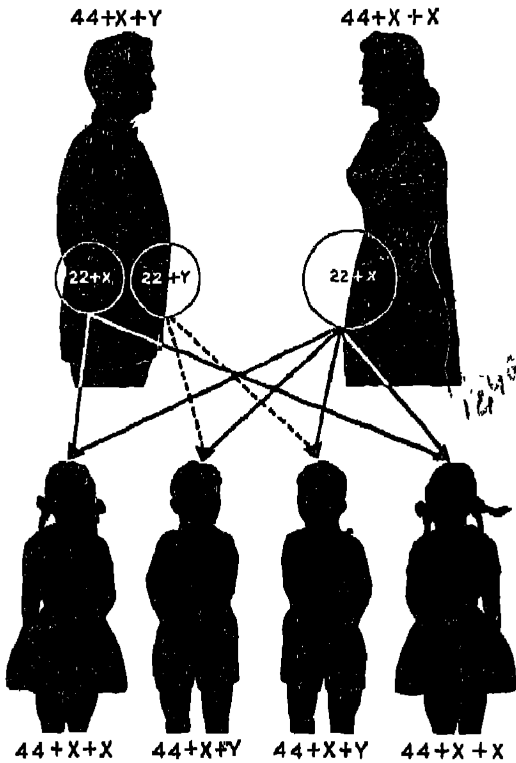


Fig. 50.5. The genetic basis of the determination of sex in man. Courtesy of the Department of Botany, University of Delhi.

in equal numbers. Theoretically, therefore, there are equal chances for a male or a female baby to be born. Actually, however, the ratio of the male to the female children may be more, or less than one. Have you ever noticed players throwing up a coin before starting the game? When the captain flings a coin, his chance of getting a head or a tail is 1 : 1. It may so happen that in the first five or six throws he gets only heads, only tails, or an unequal number of heads and tails. It is the same with the babies. A couple may have only daughters, only sons, or some daughters and some sons, depending upon the kind of sperm fusing with the egg. From among millions of sperms which kind effects fertilization can never be predicted. Although quacks still sell potions for begetting babies of one or the other sex, there is no scientifically accepted way of controlling the sex of a baby.

The mechanism of **sex determination** described above is now known to operate in many animals and plants. A well-known example of an animal showing the XY mechanism is the fruitfly (*Drosophila melanogaster*). In certain other organisms such as reptiles and some insects, the reverse mechanism has been recorded—the males are XX and the females XY. In birds the males are XX, but the females are just X or XO.

How is colour-blindness inherited? Have you known some people who cannot distinguish between red and green or some other colours? Strangely enough, women rarely suffer from this defect and yet, a man always inherits this defect from his mother, never from his father. The gene determining **colour-blindness** is carried in the X-chromosome. The Y-chromosome does not carry any gene connected with colour perception. Moreover, the gene for normal colour sight is dominant over the gene for colour blindness. Let us call these C and c, respectively. Remembering that men always have 44+XY, and women 44+XX, the genetic basis of the occurrence of colour blindness will be as shown in figure 50.6. It is easy to see from the figure that since the X-chromosome in man is always derived from the mother, he can inherit this defect (in the form of a recessive gene) from his mother, never from his father.

If a normal man marries a woman who is seemingly normal but carries the hidden gene for night-blindness, the pattern of inheritance would be as shown in figure 50.7.

It will be an interesting exercise for you to work out the possible results of marriages between a colour blind man and a similar

woman; and a colour-blind woman and a normal man.

How dark-haired parents get blond-haired children. Unlike the gene for colour-blindness, the gene for hair colour is not located on the sex chromosome (actually there are several genes for this character, but to simplify matters we shall consider that it is governed by a single gene). Therefore, both boys and girls may have black or

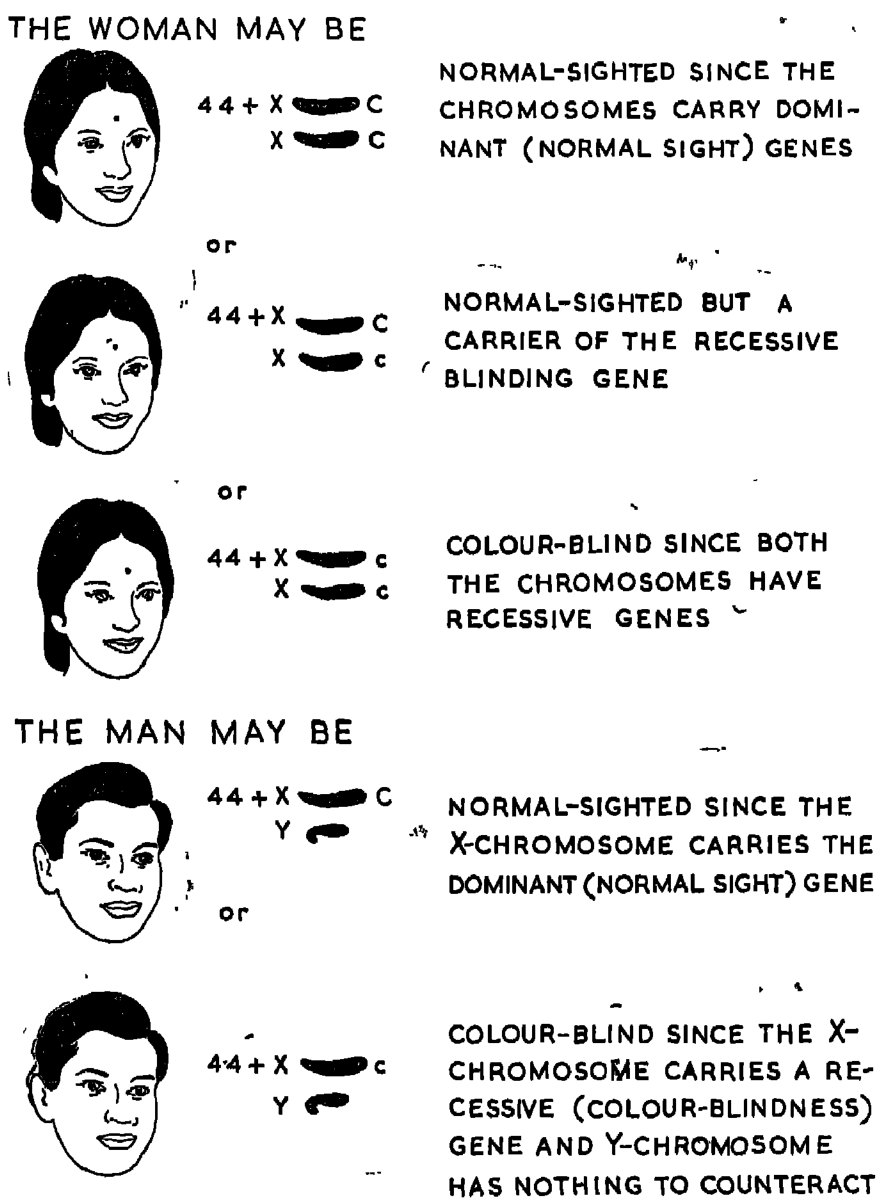


Fig. 50.6. The distribution of genetic factors for colour-blindness in a man and a woman. Courtesy of the Department of Botany, University of Delhi.

blond hair. The gene for blond hair is recessive to the gene for dark hair. If the children of dark-haired parents are to have blond hair, it is essential that both the parents must carry and contribute the hidden genes for blondness. Try to work out in genetic terms the inheritance of this character. Instead of writing the complete chromosome numbers, you may put down only the genes controlling the hair colour.

Some traits are inherited together. Mendel had suggested that if the two organisms differ in several characters, the inheritance of one is independent of the inheritance of the others. This was true of the seven characters studied by him. Subsequent work has, however, shown that this may not always be so. Imagine 20,000 genes distributed over 46 chromosomes in every human cell ! Each chromosome will naturally have several hundred genes on it. Now if you recall that in meiosis the chromosomes are distributed unbroken, you would realize that all the genes carried on a particular chromosome would always remain together and would be inherited as one unit. Such genes are called **linked genes.** Let us consider an imaginary case to understand this more clearly. Suppose that the genes for flat nose and tall stature are carried on the same pair of chromosomes. If that be so, every tall person will necessarily have a flat nose. Don't forget,

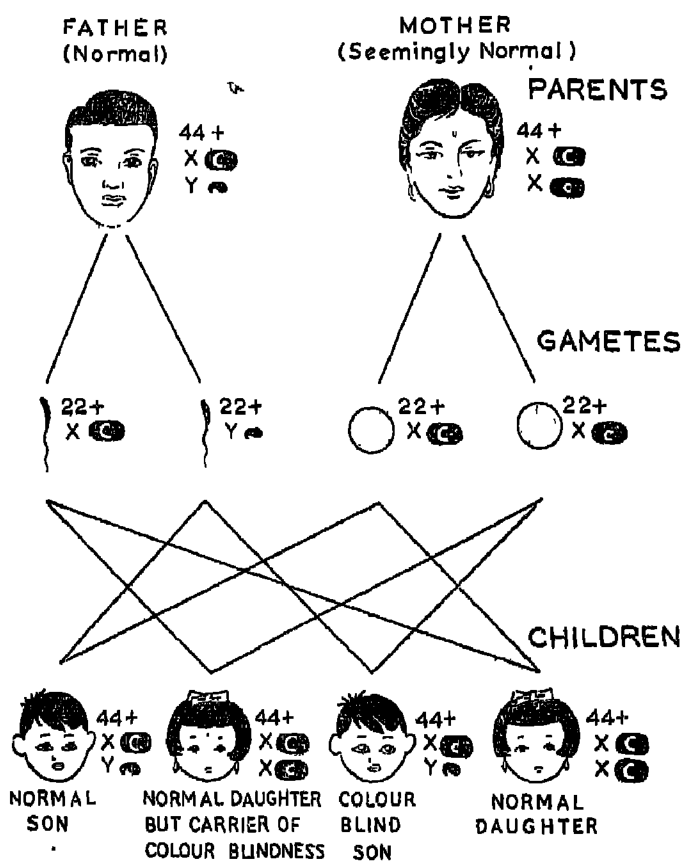


Fig. 50.7. The inheritance of factor for colour-blindness by the children of a normal man and a seemingly normal woman. The man always inherits this disease from his mother. Courtesy of the Department of Botany, University of Delhi.

however, that it is only an imaginary example.

There are certain genes which are present on the sex chromosomes, and therefore the characters they control occur only in one of the sexes, usually the male. Such genes are called **sex-linked genes.** One of the ~~serious, and often~~ fatal, sex-linked genes is the one that causes haemophilia. In a person suffering from this disease the blood lacks the capacity to clot. Normally when there is a superficial cut on our body, the blood oozes out but soon forms a clot and stops its further flow. But in haemophilic persons a slight wound may make the patient bleed to death. Another sex-linked gene causes some kind of mental deficiency. Like colour-blindness these defects occur mostly in men, women rarely suffer from them, though only they can transmit the genes.

How a mentally deficient child is born to normal parents. As a result of intensive studies of the family histories of many mentally deficient people it has been found that the gene for mental deficiency is recessive. If the parents of an idiot are normal, it evidently means that they must be carrying the hidden or recessive genes for the defect. Let us represent the normal gene by B and the recessive one by b. Thus symbolizing only the concerned genes, we arrive at the results shown in figure 50.8.

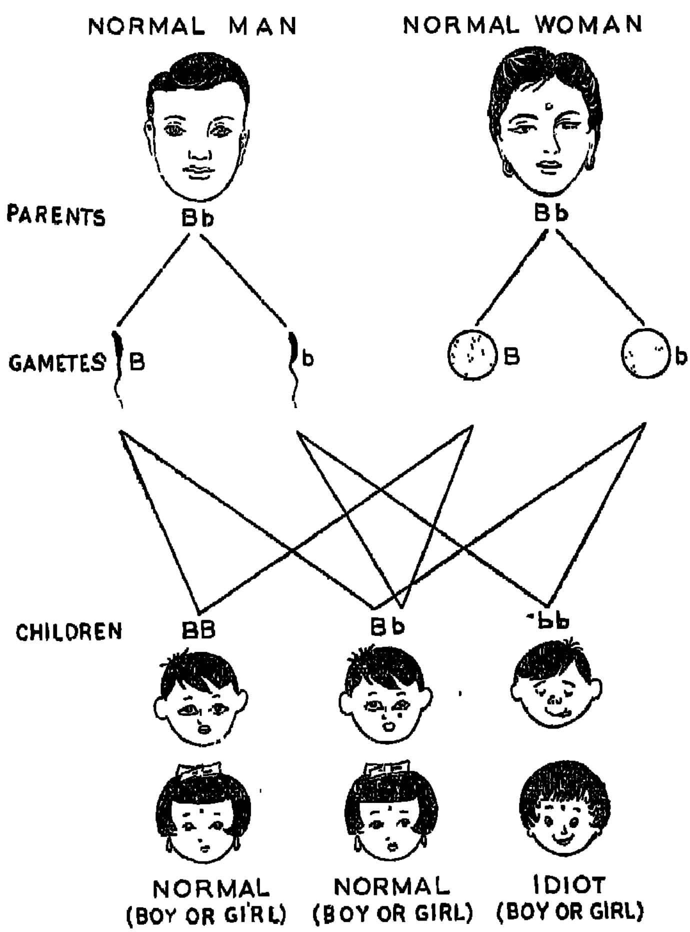


Fig. 50.8. The inheritance of factors for normal mind, and idiocy (mental deficiency). Courtesy o the Department of Botany, University of Delhi.

Heredity and Environment

You read earlier that an important factor causing differences among organisms is **environment.** This includes all the external influences such as food, climatic changes, society and so on. Let us consider some striking examples of the effects of environment. The average yield of rice in India is 360 kg per acre. With proper manuring and irrigation (i.e., with proper environment) the same variety of rice may increase its yield to 800 kg per acre. Again, a plant kept in the dark becomes yellow, thin, and elongated although it would be quite normal if it were kept in light. Honey bees provide another remarkable example of the far-reaching effects of the type of food. The larvae of the honey bee fed on only pollen grains develop into sterile female bees or workers; those fed on pollen plus a special kind of jelly develop into fertile female bees or queens. Another factor of environment, temperature, has been shown to have spectacular effects on the fruitfly. Depending upon the temperature at which they are allowed to breed, the fruitflies produce daughter flies with one or the other type of wings (Fig. 50.9). In man the deficiency of vitamin A in the food leads to various kinds of ailments such as retarded growth, night-blindness and poor resistance to other diseases. The same person on normal diet would possibly stay in good health. Consider another example. The deficiency of iodine in our food causes retardation of physical and mental development whereas a proper supply of iodine supports normal development. These instances might prompt you to ask: Are iodine, vitamin A, light, temperature and water more important than the hereditary make-up? In other words, which is more important: Heredity or environment?

The role of heredity. All specific characteristics, by which one species is distinguished from another, are inherited. A pigeon is different from a potato because it has inherited, by way of its germ cells, the racial characters which the parent pigeons possessed. No change in the environment could possibly make a pigeon become a potato, or a potato become a pigeon.

Among the pigeon's inherited characters are its morphologic structures, such as the size, colour and shape of feathers and other organs. It has also inherited many physiologic characters, such as the pulse rate, body temperature, mode of digestion, and length of life. In addition, it has also received from its parents certain other qualities which distinguish it from other birds. Similarly, a man is a man and not some other animal chiefly because of his heredity.

Not only this, the characters which distinguish one individual pigeon from the other, or one human being from another, are also hereditary. One man differs from the other in the character of his hair, the colour of his eyes, the shape of his head or nose, the size of his ears, the length of his fingers, the form of his foot, the pattern of baldness, and even in such minute characters as finger prints. We know that these too are determined by his genes.

Physiologic differences between individual men are also inherited. The fat man is fat first of all because of the kind of metabolism inherited by him. Although his inherited tendency may be controlled to a certain extent by diet and exercise, it will do him little good to envy a thin man. Similarly, eyesight, good or bad, may depend primarily upon heredity. The man who goes bald

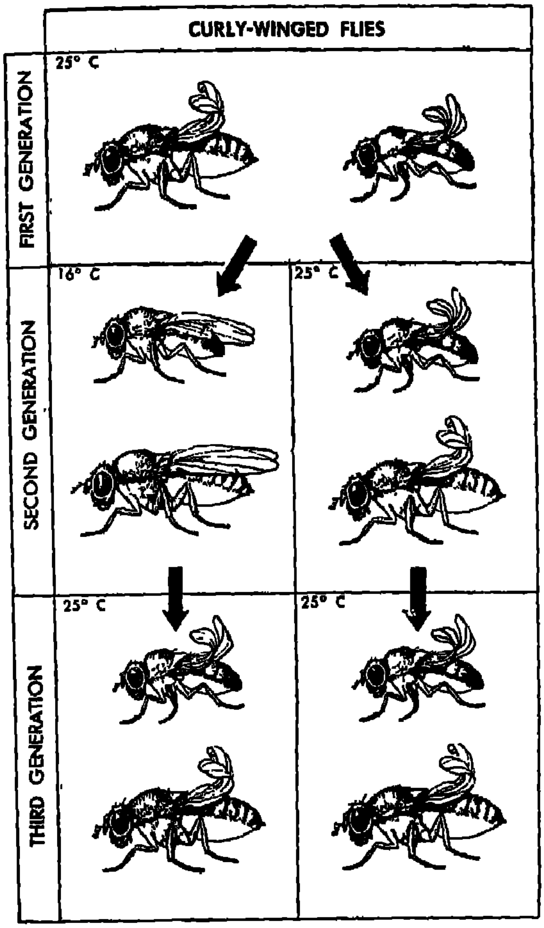


Fig. 50.9. Effect of temperature on the expression of curly wing trait in *Drosophila.* From BSCS, *Biological Science: Molecules to Man*, Houghton Mifflin Company, Boston, 1963.

at thirty, and the one who retains bushy hair at seventy, have different kinds of heredity.

Differences in the mental qualities of individual men may also be governed by inheritance. The extent of one's control on his nerves, the way one thinks, a good or a bad memory, quickness or dullness in seeing a point of view, and other similar characters are connected with the genes received from one's ancestors. The easy-going, exuberant person who doesn't worry about things is so, at least in part, because he has inherited a mind that works that way.

Each man comes into existence with an inheritance whose importance must never be forgotten. That all men are born equal is not true biologically. This may be legally all right, but it is not a biological truth. In fact we differ greatly in our biologic make-up. No teacher would agree that the mental capacity of all the children under his charge is the same and that the differences in ability are only the result of environment.

The effect of environment. If heredity controls so many things, what is the role of the environment in which an organism lives? This point may first be discussed with reference to a familiar animal like the cow. If we want a high yield of milk from a cow, we must house it properly, feed it well, milk it at regular hours, and take the advice of a veterinary doctor if anything goes wrong with it. By such means one can perhaps increase its yield of milk appreciably. However, there is a limit beyond which the yield would not rise. This limit is set by the heredity of the cow. For a still higher yield of milk it would be necessary to change this cow for one of a superior breed.

Concerning plants, by supplying proper quantities of water and nutrients, by reducing competition with weeds, and by killing the plant's natural enemies like insects, fungi, bacteria and viruses we can maintain it in optimum health and improve its performance. In a country with an underdeveloped system of agriculture even such ordinary methods can produce spectacular results. A mango tree that is hacked by somebody's knife becomes infested with insects or fungi, and the poor mangoes borne on such a tree are due more

to their environmental misfortunes than due to their genes. On the other hand, you may keep a 'desi' mango tree under the best possible environment and still it would not give fruits of the 'chaunsa' or 'langra' variety.

An important question is: In what way does heredity influence the life of living beings and in what way does environment do it? We may conclude that it is the way in which the two are combined that makes an individual. Heredity provides the equipment, environment decides how much of that equipment may be used. Without an opportunity to use it, a man's heredity is worth little. The chance for receiving education or the lack of education, good or bad companions, a poverty-stricken home or a happy one with normal advantages, all of these things (the so-called environment) help determine what one becomes after he is born.

Many characters which are determined by genes may be changed by environment. Sound lungs may be spoiled by infection, or a poor posture, or the lack of fresh air. Normal eyes may become weak through careless use of them. Natural dark hair may turn grey because of age, or nervous tension, or the use of hydrogen peroxide.

Good inheritance is worth nothing if it is not properly preserved and used. Even poor characters may become valuable if they get into an environment that will help them improve. One who inherits weak lungs is not doomed to become tubercular, for good care and a healthful climate may arrest the trouble.

These facts hold out an important signal: Since we have no control over our heredity, we may get much credit for choosing the right kind of environment.

Are Acquired Characters Inherited?

Leaving aside the exceptional cases of some rare human beings whom no environment can tempt or corrupt and who will instead change the environment itself, we must admit the powerful effect of the surroundings on the growth and development of a plant or an animal. It is, therefore, natural that our agriculture is dependent upon water, fertilizers and methods of controlling diseases. With regard to animals it is well known that a circus trainer can alter them in a remarkable way. A teacher can also mould his pupils to a certain extent. There is, therefore, a strong and natural desire on the part of so many people to see some of this good effect carried over to the next generation. Every father and mother, for example, would be happy if their attainments could be passed on in some measure to their children. Any theory which promises this would have the warm support of those who engage in wishful thinking. Alas! the facts are unfortunately otherwise.

In glass houses, under experimental conditions, by modifications of light, temperature, humidity, soil and nutrients, one can make a plant produce more or fewer leaves, flower early or late, yield more grain or less, become tall or short, but the plants grown from its seeds do not show these effects unless the same artificial environmental conditions are provided.

Many other critical experiments carried out on plants as well as animals have failed to establish a single case of the transmission of an acquired character. Such ideas no doubt make a quick appeal to masses, for they seem to promise an early removal of human inequalities. Quacks can exploit them but they have no scientific basis. Inevitably we must abandon the belief that what we do in our lifetime to improve ourselves, physically and mentally, can be passed on to the next generation. There is one comforting aspect, however. If we

cannot pass on the good, we likewise cannot pass on the evil habits we may acquire in our lifetime. Unlike other animals, man can write down his personal experience and intellectual attainments. The next generation may make further addition and so the stock of knowledge increases. Our great-grand-children will thus be in a better position than we are. But this is not hereditary or biological transmission of knowledge.

Changes in the Genes—Mutations

We have stated earlier that 'like begets like' because the genes from parents are passed unchanged to the offspring. This should not be taken to mean that genes can undergo no change at any time. Rather it means that the mechanism of cell division, the process by which new organisms are formed, is so designed that a new set of chromosomes, exactly similar to the original set, is produced before the division is completed. In this way the genes of the offspring are exactly similar to the parental genes.

Sometimes, however, a parental gene suddenly becomes different from what it was earlier. A change in the gene is called **mutation.** When a cell with a mutated gene divides, the altered gene is duplicated. If mutation occurs in some of the ordinary body cells (somatic cells) which do not take part in reproduction, it is neither detected nor transmitted to the offspring. However, if a mutation occurs in the reproductive cells there is a chance of its being perpetuated in the subsequent generations. The mutated gene no longer produces the same effect as the original one.

The first mutation was recognized in 1910 in the fruitfly (*Drosophila melanogaster*) by T.H. Morgan. The fruitflies normally have red eyes. One day Morgan ~~noted~~ a white-eyed fly amidst his collection of red-eyed flies. By mating this fly with normal ones he discovered that the white eye colour in the original fly was due to a change in the gene, since this character could be inherited by the offspring. In other words it was a case of mutation. After this initial discovery mutations have been repeatedly observed in many plants and animals.

What causes mutations? The white eye colour was obviously a case of spontaneous change due to some undetected factor in the environment. Moreover, such visible changes take place at a very slow rate in Nature—in some cases only once in a million generations. However, this phenomenon provides the means of producing variation in the organisms, and scientists therefore set themselves to finding artificial means for accelerating the rate of mutation. They subjected both plants and animals to all sorts of environmental conditions but without any significant results. However, in 1927 the American biologist H.J. Muller came out with the startling announcement that when fruitflies are exposed to X-rays strong enough to penetrate their reproductive organs, the rate of mutation could be increased nearly 150 times (Fig. 50.10). In 1946 Muller was honoured with a Nobel Prize for his work on mutations. Later it was found that mutations can also be induced by ultraviolet and gamma rays and even by the use of certain chemicals like mustard gas.

It is seen that most mutations, both natural and artificially induced, are harmful to the organism rather than useful. This is to be expected since every organism has an assemblage of genes which are delicately balanced with the environment. A change in even a small part of the whole

series would upset the balance. Nevertheless, some mutations are quite useful and have been put to use by man. The cauliflower, for instance, arose as a mutation of an original inferior type of cabbage. Most of the colourful varieties of garden plants have originated as a result of natural mutations over the past several thousand years. Seedless oranges and grapes are other well-known examples of useful mutations. Among the many artificially produced mutations mention may be made of *Penicillium notatum*, a fungus which produces penicillin. Some mutant forms of this fungus give enormously increased yields of penicillin.

Atomic explosions and mutations. Have you read in newspapers about our concern over atomic explosions? With your biological background of mutations, you can now better appreciate this anxiety. Atomic explosions release strong radiations which not only cause direct injury to the body but can also cause mutations in the reproductive cells and thus affect all the future generations. Studies on the unfortunate survivors of Hiroshima and Nagasaki (Japan), who were exposed to the strong radiations from the first atomic bomb explosion in 1945, have revealed some significant information. Most of the children born to these people were either abnormal, or still-born, or died a little later. They had often malformed body organs. These dreadful results have made all well-wishers of the human race to deplore these reckless atomic explosions.

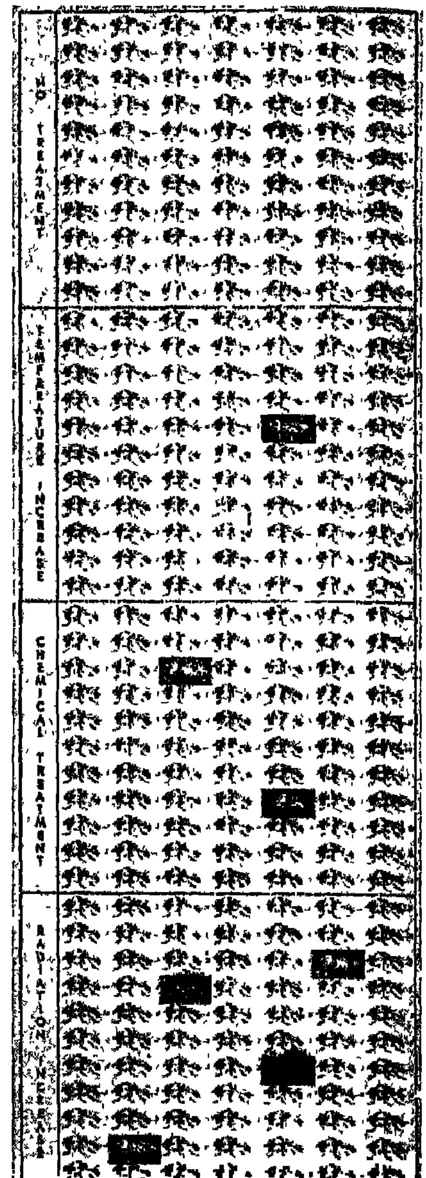


Fig. 50.10. The relative effects of temperature, chemicals and radiation on the frequency of mutation of genes of *Drosophila*. From BSCS : *Biological Science, Molecules to Man*, Houghton Mifflin Company, Boston, 1963.

Practical Applications of Mendelism

Your were told in the first chapter (p. 3) that '. . . . the long history of science reveals that the greatest benefits have resulted from researches that were carried out to satisfy curiosity rather than with a hope of gain'. Mendel's work on peas is a glowing example

of the unlimited rewards of fundamental research. His experiments were not aimed at obtaining any material gains. He was simply driven by curiosity to find out what types of pea plants would result if true breeding forms were cross-mated or hybridized. His laws of heredity had three important consequences: They dispelled ignorance and confusion about many mysterious happenings; they provided the necessary inspiration for further work which has continued ever since with an ever increasing tempo; and thirdly, an intelligent application of Mendelian principles has enabled us to breed the most desirable types of plants and animals. It is no overstatement that most of our useful plants are the outcome of the scientific skill of plant breeders. With a knowledge of genetic principles at their command they can produce new combinations of characters, 'tailor-made' to fulfil particular requirements of soil and water availability or resistance to diseases and pests. Although man has attempted to bring about some sort of improvement in his plants ever since the beginning of agriculture, such attempts were largely a hit-or-miss affair. The application of genetics made this work more precise and rewarding.

Let us recount some instances in which Mendelian principles have cleared the mystery around certain beliefs and happenings. We have learnt that characters can be transmitted from parents to children only through the gametes, or more precisely, through the chromosomes in the gametes. Therefore, only such characters of parents would be transmitted which can affect the gametes. Thus, if the parents suffer from any diseases, injuries or deformities in their lifetime, these cannot be passed on to the children. This equally applies to any good qualities that the parents might have acquired. Thus the children of an artist or a scientist should nurse no hopes of aquiring their parents' virtues except through their own efforts and through their constant association with their parents.

Mendel brought out the idea of dominant and recessive characters. The recessive characters express themselves only when two or more of them happen to combine together. This immediately explains how a child having certain characteristics may be born to parents who show no such characteristics. Several examples of this kind have been given earlier.

A knowledge of the principles of genetics may enable us to improve the human race itself. It is true that none of us can change our hereditary make-up in any way, but it is possible to control the future combination of characters by selecting suitable marriage partners. Such control is especially important for those persons who have certain heritable defects like feeble-mindedness and diabetes.

More about Genes

The chemical analysis of the nuclei of any organism shows them to be composed chiefly of nucleoproteins, i.e., compounds of proteins and nucleic acids. The two nucleic acids are ribonucleic acid (RNA) and deoxyribonucleic acid (DNA). There is decisive experimental evidence to show that the nucleic acids are the real controlling centres of all cellular activities. Further, it has been shown that DNA is perhaps the chief hereditary chemical. One or more molecules of this master chemical constitute a gene. The genes of all organisms contain DNA and yet, the DNA of every species, or for that matter of every individual, is in some way different from the DNA of every other individual. DNA can manifest itself in as many forms as the number of kinds of living organisms, perhaps well over two

million. The DNA molecule is a giant molecule, though not big enough to be clearly seen under even the highest available magnification. It is made up of the five commonest elements—hydrogen, oxygen, carbon, nitrogen and phosphorus—which are present in the form of six chemical compounds. In structure, the molecule is like a twisted ladder. The main limbs of the ladder are made by alternately placed sugar and phosphate groups. The rungs that connect the limbs contain four nitrogenous compounds called adenine, thiamine, guanine and cytosine. Each rung has only two of these compounds always in just two combinations, namely, adenine—thiamine or guanine—cytosine. Being a gigantic molecule, a single DNA ladder may have thousands of these groups. Depending upon the sequence of nitrogenous rungs in the molecules, infinite types of DNA can be formed. That is how all the two million kinds of organisms have each a specific type of DNA. The spring-like molecules lie tightly coiled inside the chromosomes.

DNA is a peculiar chemical in several ways. It has the capacity to loosen or tighten its coils; it has the ability to split into two longitudinal halves, like the halves of a zipper, and each half can again complete itself by picking up and joining together more nitrogenous compounds as well as sugars and phosphates, from the cell cytoplasm. DNA is a master chemical that not only transmits the hereditary information but also controls the orderly development of the organism. It directs, for instance, when, at what place, and what type of an organ would be formed. You may next ask: How does DNA do all this? Well, that is something on which the biologists are still working. Experiments of several groups of workers show that genes exercise their control by releasing specific kinds of RNA which direct the formation of proteins in the cell. Some of these proteins act as enzymes, and the latter, as you have already learnt, run all the chemical processes of the cell. We shall report only one investigation which has demonstrated the control of enzyme formation by specific genes.

There is a certain disease called **alkaptonuria** in which the urine of a patient becomes black on exposure to the air. This is due to the presence of a compound called alkapton in the urine. The case histories of the alkaptonuria patients revealed that the disease runs through families, and is inherited as a recessive hereditary factor. Wherever two or more recessive genes occur together, this disease manifests itself. It can be inferred that the presence of the corresponding dominant gene results in a normal condition. Further work has shown that the blood of normal persons contains an enzyme which can break down alkapton, and that diseased persons lack this enzyme. It is easy to see that with the presence of a dominant gene the body can produce the alkapton-breaking enzyme, whereas its absence causes a lack of synthesis of the enzyme. The chain of reactions leading to the final breakdown of alkapton is blocked in such cases.

Many questions regarding the exact mechanism of enzyme release are still unanswered and pose some fascinating problems to those engaged in this aspect of biological research.

SUMMARY

Genetics is the study of the causes of resemblances and differences between the parents and offspring. The differences or variations are both hereditary and environmental.

Gametes are the hereditary bridge between the parents and the offspring. The nuclei in the gametes carry a set of chromosomes equal to half the number contained in the nuclei of the ordinary cells. The chromosomes carry the tiny hereditary units called genes. When the gametes unite, the chromosome number in the zygote is doubled, and the resulting individual comes to possess a mixture of paternal and maternal characters. Due to a very precise duplication of the chromosomes during cell division, the characters of parents are normally transmitted unchanged to the progeny. Sometimes, however, the genes may undergo a permanent heritable change or mutation. During subsequent divisions of such mutated cells the altered genes are again faithfully duplicated and passed on to the progeny.

Gregor Mendel is regarded as the father of modern genetics. He formulated the first-ever laws of genetics in 1865 but his results caught the attention of the scientific world only in 1900, sixteen years after his death (1884). He crossed many varieties of peas, and from a mathematical analysis of the results he came to the following conclusions:

1. Every hereditary character is governed by two factors. When the characters are actually expressed, one factor may dominate over the other, the recessive factor. Today we call these factors the genes. An individual carrying a dominant as well as a recessive factor for any character is called a hybrid, whereas one possessing a pair of either dominant or recessive factors is known as pure with respect to that character.

2. The dominant and recessive factors in a hybrid do not blend with each other, but separate out uncontaminated during the formation of gametes.

3. In every new generation there is a recombination of factors from the two parents and the new generation may show all conceivable combinations of paternal and maternal characters.

4. The factors controlling the various characters are inherited independent of each other.

Mendel's laws have also been found to hold true for other organisms, although several exceptions and modifications have also been noted.

The sex of an individual is determined by some of the genes on the sex chromosomes. In man as well as in many other animals the female carries two X-chromosomes while the male has an X and a Y-chromosome. In reptiles, the reverse mechanism operates. In birds the males have two X-chromosomes, the females just XO. The other genes which occur on the sex chromosomes are called sex-linked, and the characters associated with them occur in members of a particular sex.

While most specific characters are governed by heredity, an organism is finally a product of the interaction between heredity and environment. Neither works alone.

Application of genetic principles to plant and animal breeding has resulted in a

tremendous improvement of domestic organisms.

Genes are hypothetical units made of complex nucleoproteins, of which the nucleic acid part or DNA is the master substance. It has the power of self duplication and of directing the synthesis of proteins, including enzymes.

Sometimes the genes undergo a spontaneous change or mutation. The rate of mutation can be increased by exposure to X-rays, ultraviolet rays and gamma rays, or by the use of certain chemicals. The danger from atomic explosions is the release of large doses of radiations which might cause harmful mutations in man and other organisms.

QUESTIONS

1. What is the significance of meiotic division in the life of a sexually reproducing organism?
2. Mark the following statements as true or false:
   (a) The sex of an unborn baby is influenced by stars, climate and mother's diet.
   (b) Fat mothers usually bear more sons than daughters.
   (c) Thin and lean parents produce more daughters than sons.
   (d) The sex of a child is determined at the time of conception and depends upon the type of sperm fertilizing the egg.
   (e) More boys are born in winter than in summer.
   (f) If a couple has only daughters, the blame for this situation must go to the mother.
3. Define genes. Where are they located? How do we know that they really exist, since no one has ever seen them?
4. Explain how all the cells in your body come to possess 46 chromosomes.
5. You might have heard people say: 'He has Rajput blood in him, and can never accept defeat'. How will you say this in genetical terms?
6. What are recessive and dominant genes? Give four examples of each.
7. Knowing that idiocy is sometimes caused by a recessive gene carried on an X-chromosome, show by means of a diagram how two normal parents may have a male idiotic child.
8. Experiments exactly similar to those of Mendel were carried out by several earlier workers but they did not draw similar conclusions. What, then, was the main reason for Mendel's significant results?
9. Explain the main difference between the Mendelian and pre-Mendelian concepts of heredity.
10. Now that you have some background of genetics, list some false beliefs about inheritance common in our society.
11. What is a mutation? What is the biological explanation for our great concern over the increased atomic radiation in the atmosphere?

12. People often ask: 'Which is more important—heredity or environment?' Explain what is wrong with such a question.

13. Identical twin brothers were separated at the age of two and brought up under very dissimilar conditions. At the age of 16 one showed a much higher I.Q. (intelligence quotient) than the other. What does it prove?

14. Explain why, apart from social considerations, marriages between near relatives are not advisable.

15. Discuss why it is important to consider the heredity of the families before a boy and a girl are engaged.

16. What is the genetic difference between a pure tall and a hybrid tall pea plant? How will you test whether a given tall plant is pure or hybrid?

17. State the three laws of Mendel.

18. After you have read through this chapter try answering the questions listed at the beginning of this chapter.

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CHAPTER 51

Organic Evolution

FOR many centuries it was believed that the earth, stars, plants, animals and man were all specially created by God in just six days, and that since then they all have been there in the same form in which they were first created. In other words, it was thought that the characteristics of living things were fixed or permanent, although all organisms were not considered equal. The great Greek biologist Aristotle (384-322 B.C.) recognized a definite gradation in forms of life. He thought that the various organisms formed a series, the so-called **ladder of life** from the 'lower' to the 'higher' forms. Plants, sponges, worms and snails were considered inferior to or 'lower' than certain other kinds of organisms like snakes, mice, cats and dogs. These animals in turn ranked 'lower' than cows, horses, monkeys and lions. But even the believers of this concept saw all organisms as independent creations of God, brought forth at almost the same time.

However, this view of a static or changeless universe did not appeal to all scientists. Many noted the existence of intergrading species of plants and animals in Nature, and they could even artificially breed new varieties of them. They also visualized, on the

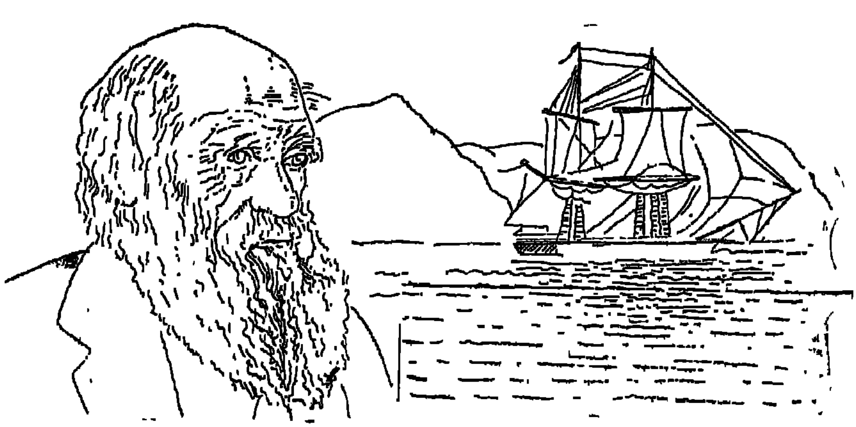

Fig. 51.1. Charles Robert Darwin (1809-1882), the author of the Theory of Organic Evolution by Natural Selection.

basis of sound data, that the earth and its atmosphere had undergone considerable changes during the past. Thus, not only the living organisms but even the physical components of the universe seemed to be changing.

Although these ideas were shared by many people it was not until the middle of the eighteenth century that they shaped into a definite biological theory—the theory of **organic evolution.** The credit for presenting this theory with convincing evidence goes to an English biologist, Charles Robert Darwin. According to the concept proposed by him the present-day organisms were not created in the same form in which they exist today, but have gradually evolved or unfolded from other, much simpler ancestral forms. Further, the characteristics of organisms have been changing in the past; they are changing even today, and will continue to do so in the future as well. The theory also postulates that the changes in the past resulted in the appearance of different aggregations of organisms, of which some are still existing while others have become extinct. The origin of new forms—sufficiently different to rank as new species—is a gradual and extremely slow process, requiring hundreds or even thousands of years. Due to the slow speed of the process no one can observe the complete transition of one form into another but the intergrades are common. In general, evolution is **progressive,** that is, it results in more elaborate forms. Consequently most of the present-day organisms are more complex than their respective ancestors which lived in the past. The simpler ancestral forms are said to be primitive; the more complex and recent ones, advanced. Sometimes, however, evolution is **retrogressive,** i.e., it takes place in the reverse direction, and produces forms that are simpler than the original. Thus, parasitic animals such as the tapeworms with their simple organization are believed to have been derived from ancestral forms which were non-parasitic and more complex.

You would have noted that, contrary to the concept of sudden and **special creation,** the evolutionary concept visualizes a ceaseless creation of new forms from the old. This concept is among the most significant scientific generalizations. It gave a new turn to man's conception of the universe and of his own. A large number of biological facts fit in, and lend support to the occurrence of organic evolution. We shall now proceed to examine some of these.

EVIDENCES FOR ORGANIC EVOLUTION

At the time when the theory of evolution was put forth there was no known method by which one could actually demonstrate organic evolution, as one might demonstrate a physical law. In Nature evolution takes place very slowly, so slowly that it would require thousands of years to produce obvious results. And we could not have made use of recorded facts about any organism, because only recently man has started making and recording accurate observations. Most of the evidences were therefore indirect, but nevertheless quite convincing. In the twentieth century many newer biological techniques have been developed, and more extensive work on biological problems has made it possible to see evolution take place in the laboratory within short periods of only a few years. Several experiments have been done in this direction but we shall mention here only a couple of them. If organisms with very short life-cycles, such as the fruitfly and bacteria, are allowed to reproduce for several generations in the laboratory, new kinds of individuals can be detected in the progeny. Initially these individuals differ only slightly from

their parents, but as they increase in number, many small differences keep accumulating. A stage is finally reached when the slightly different organisms become so completely different from the parental forms that they would now breed or cross only with new individuals of their own type. In other words, these must now be ranked as new species.

Another line of experimental evidence comes from plant and animal breeding. It has been possible to cross two varieties or even species of organisms, and produce entirely new organisms that did not exist on the face of the earth before. Breeders have achieved remarkable success in synthesizing, or shall we say evolving, new forms by doing in a short time what Nature might do in hundreds of years. One of the earliest and perhaps the most curious examples of **experimental evolution** was the cross between the horse and the donkey resulting in a new animal called the mule. Among plants the common cabbage (*Brassica oleracea*) and the radish (*Raphanus sativus*) have been crossed to give a hybrid which has roots like those of cabbage, and leaves like those of radish—an agriculturally useless combination, but one resulting in a new genus, *Raphanobrassica*.

Many other examples exist to show that evolutionary changes do take place, and that organisms are not constant or unchangeable. Most of the other evidences outlined below are less direct.

Palaeontological Evidence

Palaeontology is the study of **fossils**, i.e. the remains of ancient animals and plants preserved in the rocks. Literally the word fossil means 'anything dug out of the earth'. Actually, however, almost anything that gives evidence of the presence of organisms which lived once upon a time is a fossil. It may be an entire organism which got buried in the snow in the remote past; it may be just a mould of the foot prints or of any part of an ancient animal, or it may be only an imprint of a leaf on a stone. However, the most instructive fossils are those in which the remains of entire organisms or their parts become changed into stones, and are embedded in the rocks. "How do rocks come to include the remains of organisms?" might be the question shaping in your minds. Well, in the formation of a common type of rock, called the **sedimentary rock**, it so happens that the sand or mud from the land is washed into rivers, lakes and seas where it sinks to the bottom. Entire bodies or parts of dead organisms often become included in these layers of mud and sand. After their burial, most organisms just rot away, and leave no sign of their existence. But sometimes appropriate conditions exist for them to be changed into fossils. In this process the dead bodies or their parts may be deposited in water, and subsequently become closely covered with layers of mud in such a way that no active decay can occur. Even under these conditions the softer parts decay out but the harder parts like the wood, the leaf skeletons and the bones remain intact (Fig. 51.2 A and B). Slowly, over the centuries, the material of the harder parts also breaks away or is dissolved out, but the cavities left by it are filled with mineral matter from the surrounding mud. Ultimately the entire structure is replaced with mineral matter. The replacement is sometimes so fine that even the cellular details can be studied accurately. In the meantime more of sand and mud keeps on collecting in definite layers over the earlier depositions. With the passage of time, reckoned in thousands and even millions of years, the layers of mud shrink and harden into rocks. (Fig. 51.2 C and D). When such rocks are explored by man, or eroded by water and wind, the fossils become visible remnants of

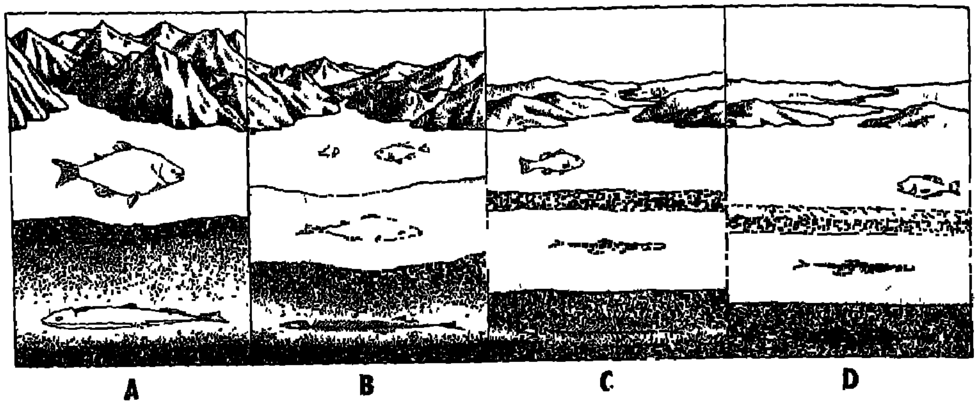

Fig. 51.2. Stages in the formation of fossils and sedimentation of rocks. From BSCS, *Biological Science: Molecules to Man*, Houghton Mifflin Company, Boston, 1963.

organisms (Fig. 51.3). Figure 51.4 shows the photographs of several fossils obtained from Bihar, Gujarat and Kashmir. It will be a fascinating experience for you to see the vast collection of plant fossils at the Birbal Sahni Institute of Palaeobotany at Lucknow. It is named after the late Professor Birbal Sahni who had been the fountain-head of extensive palaeobotanical work in our country.

Since most body parts are made of soft material, it is only the harder parts that are generally preserved. Not only that, many organisms never become fossilized at all. We, therefore, cannot expect the fossil record to reveal the full story of the past. Nevertheless, even the incomplete fossil record furnishes a very convincing evidence of evolution.

A method has been devised to calculate

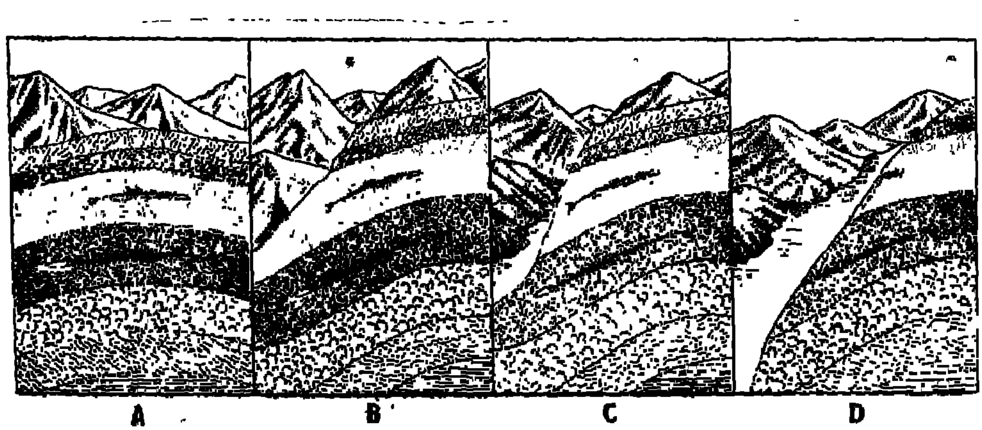

Fig. 51.3. These drawings illustrate how fossils become exposed. A. Layers of rock with fossils. B and C. Uplifting and folding of the rock. D. Erosion of rock by water exposes the fossils. From BSCS, *Biological Science: Molecules to Man*, Houghton Mifflin Company, Boston, 1963.

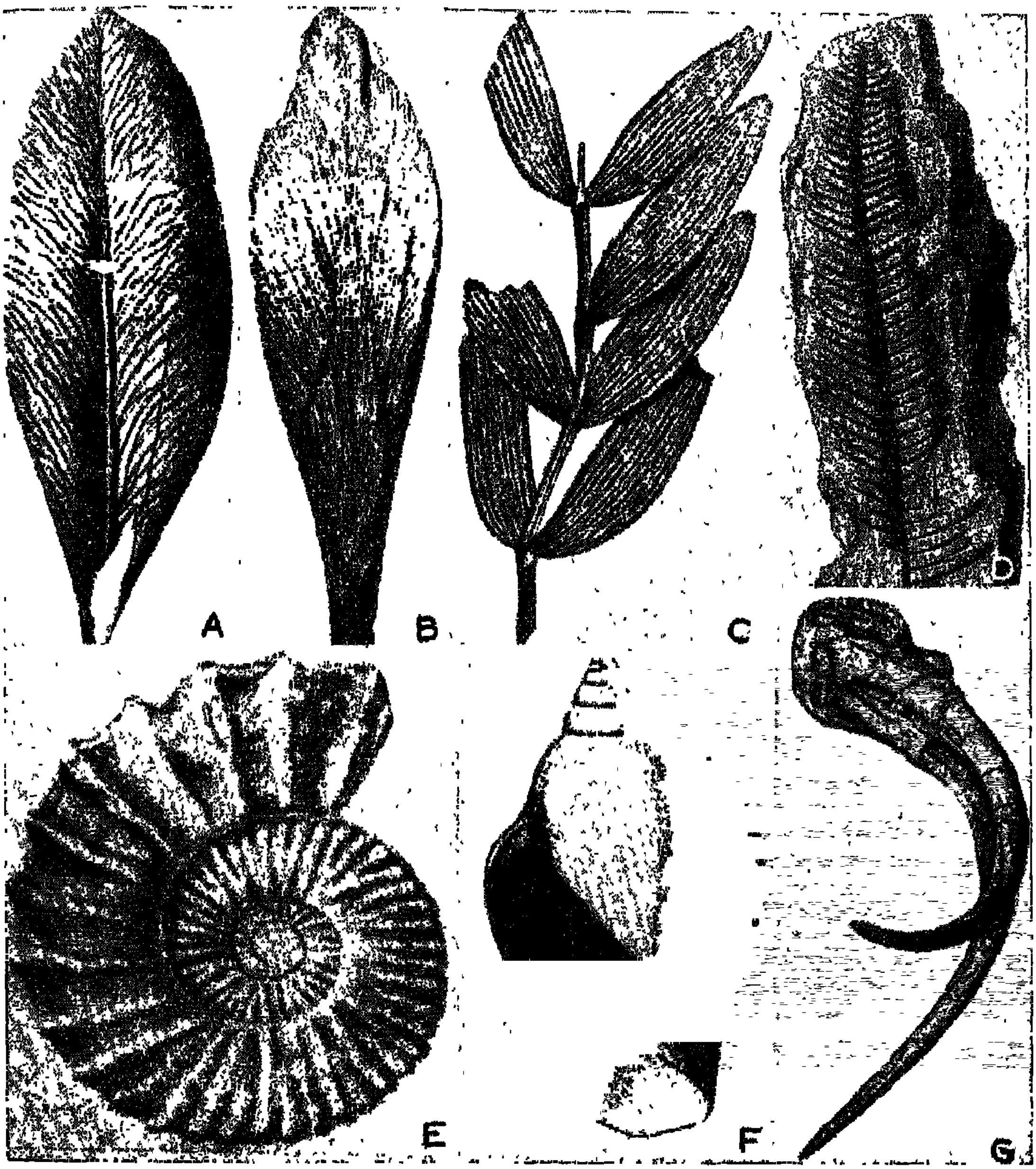

Fig. 51.4. **A collection of fossilized parts of some plants and animals unearthed from various places in India. A.** *Glossopteris conspicua*—**the leaf of a fossil seed-fern. B.** *Gangamopteris cyclopteroides*—**leaf of another fossil seed-fern. C.** *Schizoneura gondwanensis*—**shoot of an extinct horse-tail. D.** *Ptilophyllum acutifolium*—**a compound leaf of an ancient gymnosperm. E.** *Schloenbachia inflata*—**shell of an extinct mollusc. F.** *Bullinus prinsepii*—**a fossil mollusc shell. G.** *Stegodon ganesa*—**tusks of a fossil elephant.** Courtesy of the Geological Survey of India.

the age of rocks. This is based on the property of the radio-active element uranium to transform itself into lead through several intermediate stages. It has been calculated that one million grams of uranium produce 1/7,600 gram of lead in one year. Thus by determining the amount of lead in a rock, one can form a farily accurate estimate of the time of its formation.

When fossils are arranged according to their ages they clearly show that evolutionary changes have really occurred; sometimes they even reveal a fairly complete sequence of the changes. For instance, we find that the rocks of the same age from different localities of a region contain fossils of organisms of almost the same order of complexity. Further, as we proceed from the most ancient to the recent layers of rocks, the fossils also change progressively. When we approach the most recent deposits, we come across fossils of certain plants and animals resembling present-day forms. Indeed, the correlation between the rocks of a particular age and the type of fossils is so close that the occurrence of a particular fossil in a rock bed can fix the age of the rock. Thus by examining the fossils in a series of rock layers it is possible to know the changes in the organisms during the ages. Based on the data obtained from a study of fossils of different ages, geologists have prepared a time-table which indicates the ages of successive layers of the earth, and the types of fossils contained in them. It is a sort of calendar of the earth's past history which is divided into different epochs or eras; the eras are in turn subdivided into periods. A much simplified **geological time-table** is presented on page 575. It indicates the ages of the various eras and periods together with the major groups of animals and plants that are believed to have existed during each period. From a detailed study of geological time-table palaeontologists have arrived at the following conclusions:

(1) None of the plants and animals of the past were exactly similar to those found today. (2) The oldest forms are relatively simpler, and could match at best with the unspecialized members of the living phyla. (3) There has been a gradual progress from the simple to the complex forms. (4) It is common to find a new type appearing in one period, becoming abundant in the next, and gradually disappearing during the later periods. (5) The mammals among animals, and angiosperms among plants are the most recent products of evolution.

You can see that the various periods of the history of life covered millions of years. Perhaps you find it hard to visualize the relative sequence of events in view of the extremely slow rate at which the changes have been going on. In figure 51.5 you see the same events presented in another perspective—as if they occurred in just 24 hours. The starting point, representing the beginning of life some two billion years ago, is arbitrarily fixed at midnight. On this scale, up to 6 P.M. the living forms did not leave many fossils. At 8 P.M. plants began to invade the land, and at 8.30 P.M. insects and amphibians joined the land plants. The reptiles appeared at about 9.30 P.M. and flourished till 11 P.M. when the mammals started superseding them. Man appeared less than a minute before midnight. His entire history, his entire culture and civilization was staged only in the last one-fourth of a second. Thus you see that our cultures and civilizations, however old and ancient we may think them to be, are very recent on the evolutionary time-scale.

A rare but unique instance of highly convincing palaeontological evidence has come from the fossil history of the horse.

Geological Time-Table

Era	Period or Epoch	Years (in millions) before today	Plant Life	Animal Life
	Recent		Dominance of herbs	Human cultures
	Pleistocene	1 (or 2?)		Development of man
	Pliocene	13	Formation of grass lands	Appearance of man
Cenozoic	Miocene	27		First great apes
	Oligocene	37	Extensive spread of forests	First elephants
	Eocene	52	Diversification of flowering plants	First horses and carnivores
	Palaeocene	63		Spread of primitive mammals
Mesozoic	Cretaceous	135	Origin of monocotyledons; appearance of first oaks	Dinosaurs reached their peak and disappeared; first modern birds appeared
	Jurassic	181	Appearance of first dicotyledons; cycads and conifers abundant	First birds (*Archaeopteryx*) and first pouched mammals; dinosaurs diversified
	Triassic	230	Seed-ferns became extinct	First dinosaurs and egg-laying mammals
Palaeozoic	Permian	280	Seed-ferns predominant	Appearance of wasps, butterflies and first mammal-like reptiles
	Pennsylvanian	320	Seed ferns and horsetails abundant	Appearance of reptiles; amphibia, beetles and cockroaches abundant
	Mississippian	345	Club mosses and horsetails dominant	Echinoderms and sharks abundant
	Devonian	405	Origin of first seed plants	First amphibians; sharks and lungfishes abundant
	Silurian	425	Appearance of first vascular plants	First insects (wingless); first bony fishes and sharks
	Ordovician	500	First mosses probably arose	First jawless fishes; molluscs abundant
	Cambrian	600	Aquatic algae abundant	Trilobites dominant
Proterozoic		1500?	Appearance of algae	First molluscs and worms
Archaeozoic		3500?	?	?

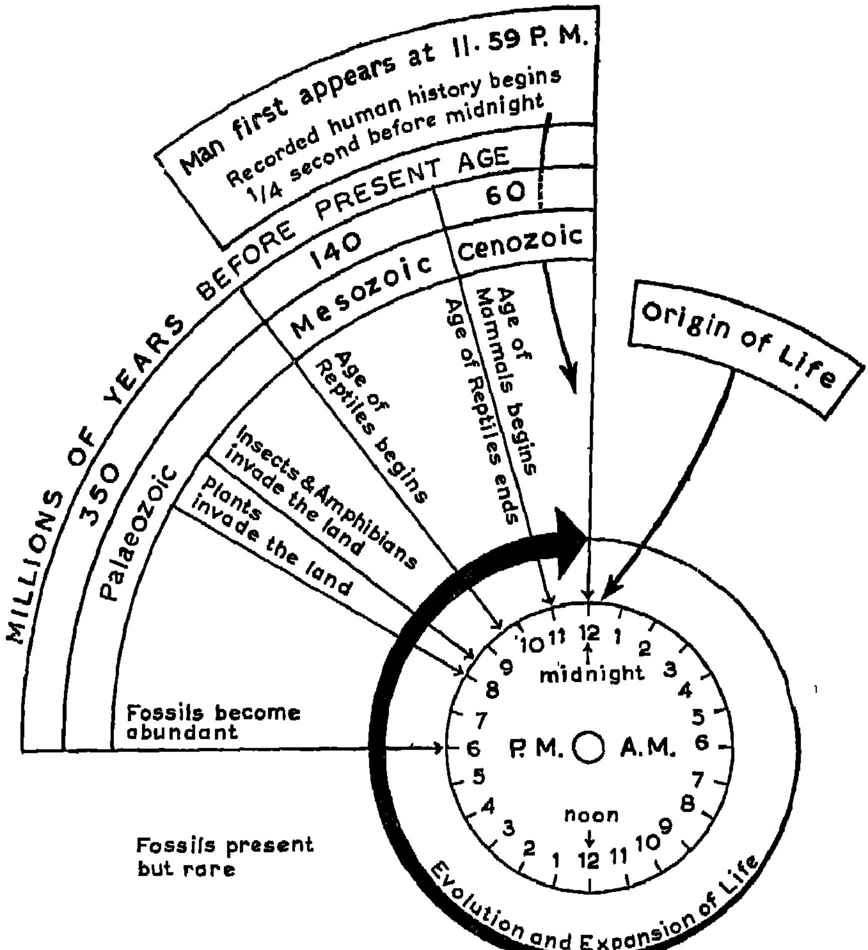

Fig. 51.5. The major events in the origin and evolution of life on the earth depicted in the form of a clock. The changes which occurred in millions of years on earth have been visualized to have taken place in 24 hours. Note the extremely slow rate of evolution till long after the origin of life. After G. C. Simpson, C. S. Pittendrigh, and L. H. Tiffany, *Life—An Introduction to Biology*, Harcourt, Brace & Co., New York, 1957.

The two important characteristics of the horse are: (1) legs well-adapted for walking at a considerable speed, and (2) teeth suited for grinding leaves and seeds. The earliest fossil of the horse is traced to the **Tertiary period** in the **Eocene era** (about 60 million years ago), and is named *Eohippus* (Fig. 51.6). This was a small creature of the size of the present-day dog, and possessed slender legs. It had four toes on its fore-foot (representing the second to the fifth digit), and three toes on its hind-foot (representing the second to the fourth digit). All these toes touched the ground and were used in walking.

The fossil horse, *Miohippus* of the next or

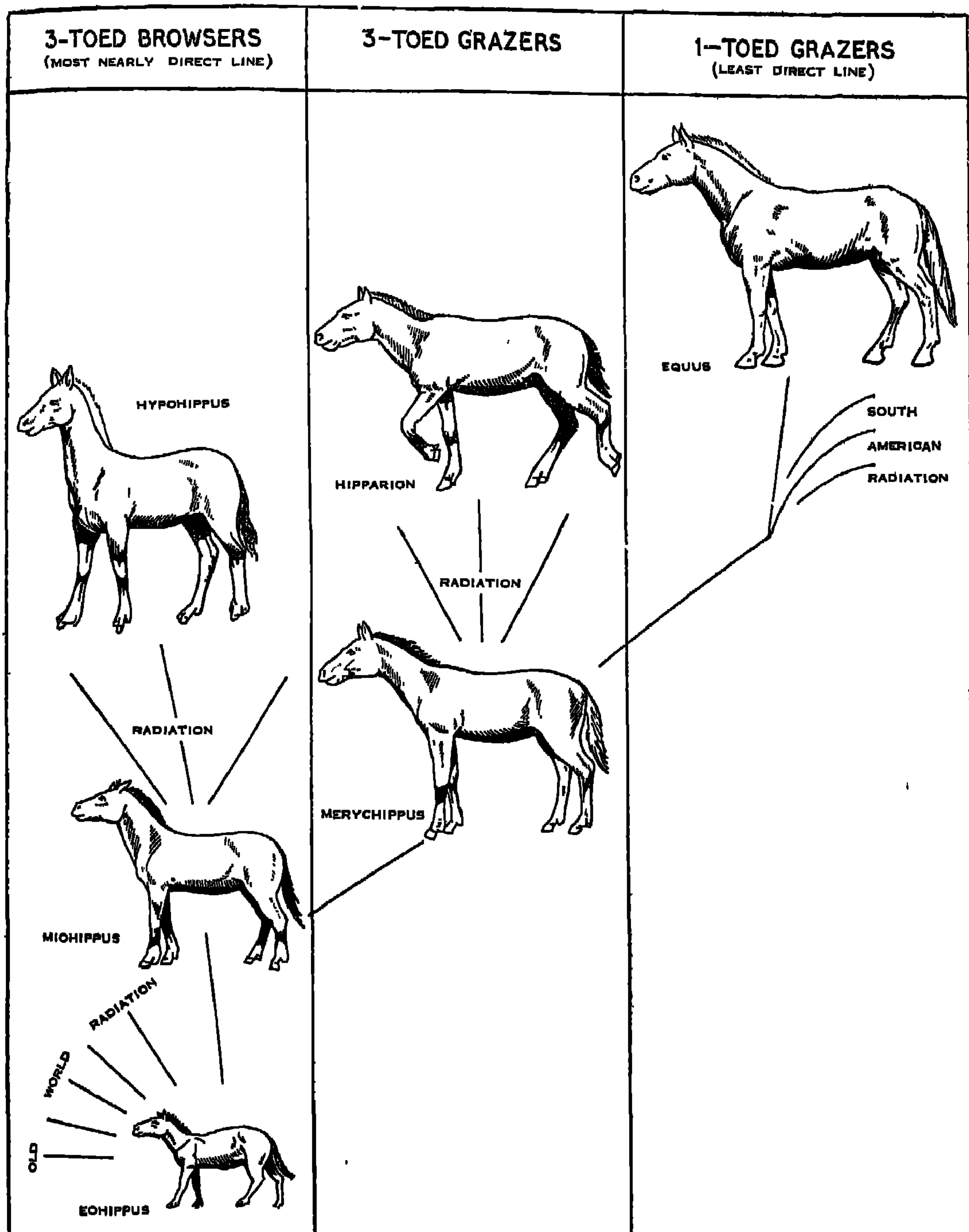

Fig. 51.6. The evolution of horse. Besides other changes there has been a reduction in the number of toes and an increase in body size. From G. C. Simpson, C. S. Pittendrigh, and L. H. Tiffany, *Life—An Introduction to Biology*, Harcourt, Brace & Co., New York, 1957.

the **Oligocene era** attained the size of a sheep, and had three toes on each of the fore - and hind-feet. In the **Miocene** the horse (*Merychippus*) had attained the size of a small pony, and had a strong middle toe supporting the entire weight of the body. The next periods—the **Pliocene** and **Pleistocene**—saw further reduction of the side toes. The present-day horse (*Equus*) has its side toes reduced to merely splint bones. The process that was operating with reference to the legs was also affecting the other parts of the body, notably the teeth and with them the mode of feeding. The lineage was of course not as simple and direct as given here, there were also many side-shoots but the main results are as described above. Fossil pedigrees, almost as complete as that of the horse, have been unearthed for the whale, camel, elephant and man.

Evidence from Comparative Morphology

Each group of plants and animals has its own unique plan of organization. In the vertebrates, for example, we find that the vertebral column, the spinal cord, the perforated pharynx, and the sense organs are all built on a common plan. Obviously such a wide-spread commonness cannot be a mere chance occurrence. Clearly there was a common ancestor from which several classes of vertebrates developed along different lines all retaining their basic plan. Furthermore, the arm of man, the flipper of whale, the paw of dog and the wing of bat, although so dissimilar outwardly, show a common structural plan (Fig. 51.7). These organs were perhaps formed in adaptation to different modes of life without any sub-

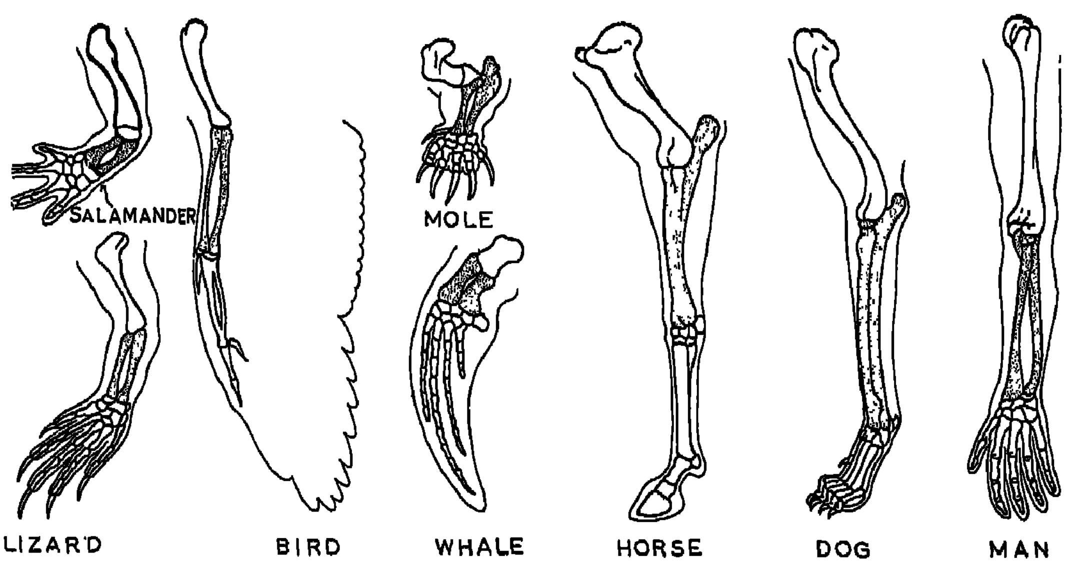

Fig. 51.7. Comparison of bones of fore-limbs of some vertebrates. The radio-ulna is shown stippled. Note the marked similarity in the pattern of bones even though the fore-limbs of the different animals have different functions. From J. Fisher, J. Huxley, G. Barry, and J. Bronowski, *Nature*, a part of the Macdonald Illustrated Library and published by Rathbone Books Limited, London, 1960.

stantial change in the original plan. This kind of fundamental similarity in the organization of apparently dissimilar structures is called **homology**. The presence of homologies can be explained only if we assume that such characters have come down from common ancestors.

In many organisms we find some structures which have apparently no function; similar structures in other organisms perform some essential functions. Such non-functional structures are called **vestigial.** The muscles at the base of the human ear are vestigial, whereas similar muscles in other mammals, like cow and horse, are functional and enable the animals to move their ears. A large number of other vestigial structures are known to be present in the human body. Some of these are shown in figure 51.8. In some plants, such as the prickly pears, the leaves are scale-like and vestigial, while most other plants possess functional leaves. In rodents the caecum is functional; in man it is vestigial. Vestigial hind-limbs occur in the form of two small bones in python. The widespread occurrence of vestigial structures can be explained only if we believe that these were once functional, but evolutionary progress has rendered them unnecessary, and they are now on way to disappearance. To think that they were just created without any purpose, as the special creationists would be forced to think, is absurd.

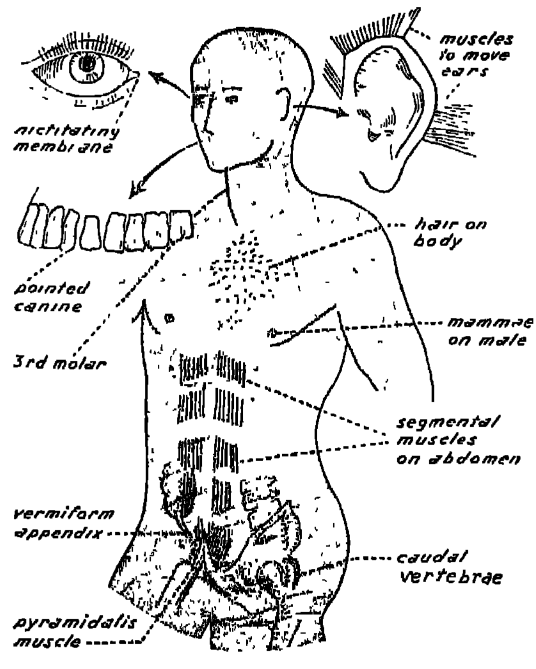

Fig. 51.8. Some of the vestigial structures in the human body. After T.I. Storer and R.L. Usinge, *General Zoology*, McGraw-Hill Book Company, Inc., New York, 1957.

Taxonomical Evidence

As you have seen in the earlier sections, it is possible to put a group of related organisms under a species. The members of one species are distinct from those of another in many respects, and yet they have some characteristics in common so that they can be put into a single genus. Likewise, many similar genera can be grouped into families, families into orders, orders into classes, and classes into phyla that form the plant or the animal kingdom. These groupings suggest that the plant or the animal kingdom may be visualized as forming a huge **family tree**. Its trunk is comparable to the common ancestral stock from which the various groups of organisms, represented by smaller and larger branches, diverged into separate or independent forms. A family tree of the animal kingdom is shown in figure 51.9. It shows the possible relationships between different phyla, all of which are to be traced back to the same ancestors. A similar family tree for the plant kingdom was presented on p. 77. The fact that the organisms can be classified into small groups which are in turn subordinate to larger ones suggests that they arose by a process of gradual modification of a common

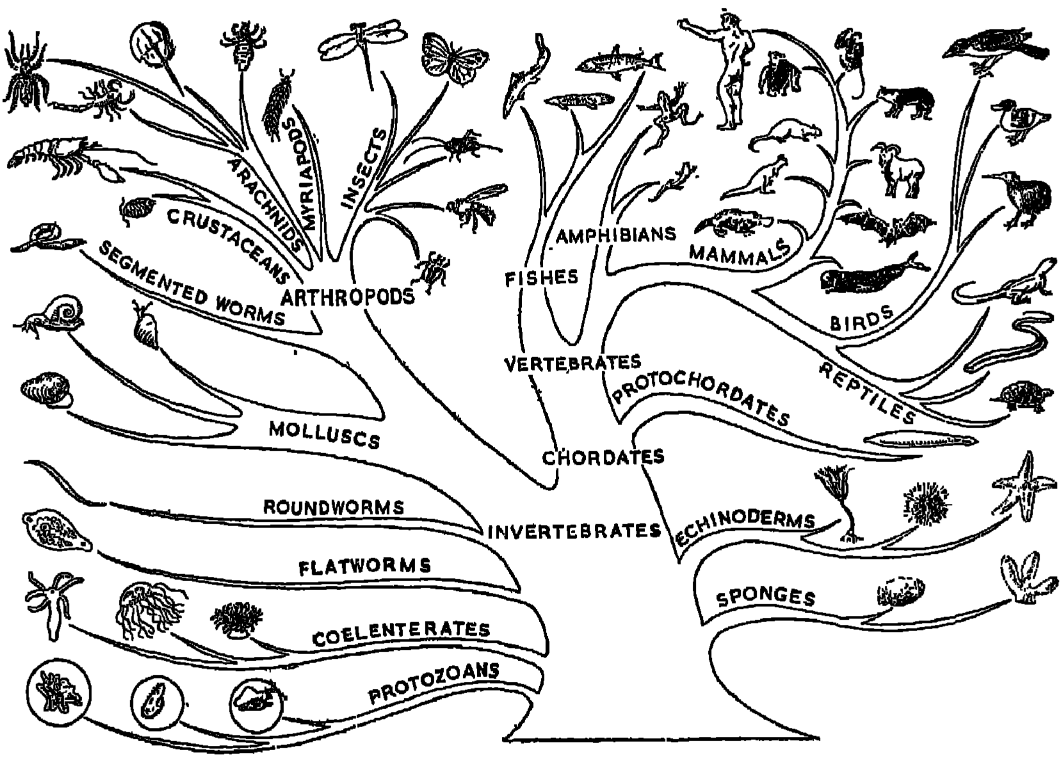

Fig. 51.9. This 'animal tree' shows the evolutionary relationships among animals. The animals shown are representatives of different groups. From C. Gramet and J. Mandel, *Biology Serving You*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1959.

ancestral stock in the course of millions of years. If each kind of organism were a product of special creation, there would be no question of their being catalogued into such groups. While some characteristics of each species are well-marked, there are others which show variations, and allow a further splitting of a species into varieties. Thus we have numerous varieties of rose, of mango, of dog and of man. In other words, there also occur over-lapping characteristics among members of a species. These can be accounted for only if we assume that the characteristics of organisms have been changing, and the overlapping forms are intermediate stages in the process.

Embryological Evidence

Embryology is the study of the developmental stages of organisms. When the embryos of various groups, especially those of animals, are studied, we find that they show remarkable resemblances (Fig. 51.10). The resemblance is so close that at an early stage even an expert embryologist would find it difficult to distinguish one embryo from the other. The similarity in the embryos is greater in those animals whose adult forms closely resemble each other. Furthermore, the development of an organism from the zygote to the adult stage seems to pass through stages that are reminiscent of the

mature forms of the animals belonging to lower and more primitive groups. For instance, we find that the earliest stages of embryonic development of man closely parallel first that of a protozoan (fertilized egg) and then that of a coelenterate (gastrula or a two-layered, cup-shaped mass of cells). After this, the embryo becomes three-layered (triploblastic). The later stages successively resemble those of a fish, an amphibian, a reptile and a bird till finally the mammalian stage is reached (Fig. 51.10).

Embryological stages in most plants are not so markedly similar, though in some they also display some resemblance. Thus the protonema of moss and the gametophyte of a fern both look like a filamentous green alga. Another interesting example is seen in Australian acacias. Unlike most acacias which have compound leaves, the Australian

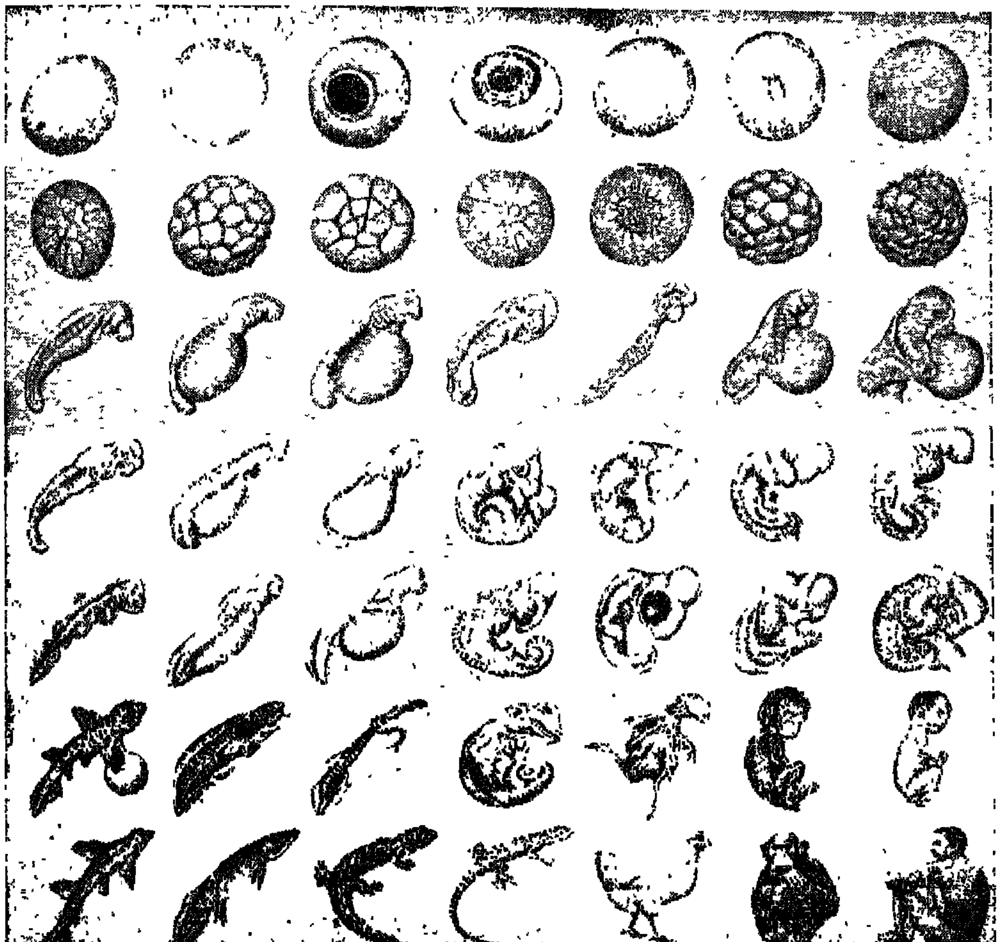

Fig. 51.10. Remarkable similarity in the early stages of development of some vertebrates. From BSCS, *Biological Science: Molecules to Man*, Houghton Mifflin Company, Boston, 1963.

species bear simple leaf-like structures which are actually the expanded petioles of the leaves (phyllodes). Nevertheless, the seedlings of these acacias bear normal compound leaves characteristic of other acacias.

The occurrence of a gill-bearing, fish-embryo-like stage in man, of an alga-like stage in a moss or fern, and of compound leaves in Australian acacias, cannot be accounted for except on the basis of evolution.

The knowledge of the occurrence of such sequences of development led Haeckel to formulate his famous **'Biogenetic Law'** or **'Recapitulation Theory'** which states that the development of an individual (**ontogeny**) recapitulates or repeats, in a condensed and even modified form, the development of the race (**phylogeny**).

Evidence from Distribution of Plants and Animals

The present-day distribution of plants and animals follows a peculiar pattern which is hard to explain except on the basis of organic evolution. In fact the conclusions derived from geographical distribution exerted strong influence in shaping the concept of evolution in the mind of Darwin and others. During his historic voyage Darwin visited the Galapagos Islands. These are a group of isolated islands in the Pacific Ocean, about 500 km west of Ecuador (South America). Darwin noticed several species of birds (now called Darwin's finches) which did not occur anywhere else. They looked like finches but were not quite similar to those found in other parts of the world. The various species in these islands differed in the shapes of their beaks and feet, and in their feeding habits. Darwin wanted to find out why a special set of birds should be present in these islands, and why there should be so many different kinds of them, each with its own particular way of life. It would be reasonable to think, as indeed Darwin did, that the remote ancestors of these birds were accidentally transported to these islands. The barrier of the sea prevented their spread to other places. In response to the conditions of life on these islands the ancestral birds gradually changed, or evolved, into the present forms.

A still more convincing evidence comes from the plants and animals found in Australia. The original or native mammals of Australia, called marsupials, are not found anywhere else in the world. They produce quite immature young ones which have to be fed and carried by the mother in a pouch until they are old enough to go about independently. Some of these animals fairly resemble the wolves, the cattle, the rats and the squirrels found elsewhere in the world, but in addition they are marsupials. How shall we account for a special group of animals here?

The geological data show that Australia got separated from the rest of the world in the remote past. It is quite possible, then, that when this continent became separated from the rest of the landmass, these animals were exposed to a particular set of conditions or influences, and were prevented from intermixing with their relatives in the other parts of the world by the barrier of vast ocean. The isolated ancestors evolved on independent lines, still retaining some of their original characteristics. Thus came into being the marsupial wolf, the marsupial rat, the marsupial squirrel and other marsupials that occur today in Australia.

Similar evolutionary processes operated upon plants, with the result that today we find many plants that occur wild, or in the natural state, only in Australia. The most well-known example is *Eucalyptus*, of which

over 500 species are known from Australia alone.

The plants and animals evolved in a particular region are said to be **native** to that place. By this an evolutionist means that the organism in question originated in that region—from ancestors which were not able to spread to other places because of certain barriers like the vast stretches of water and desert, mountains, natural enemies, and so on.

Biogeographers, i.e. the scientists who study the distribution of plants and animals in various geographical regions, have found that many geographically similar areas such as the tropical rain forests of South America, Africa and Asia have their own distinct sets of plants and animals, in spite of having almost similar climates. The most likely explanation of such divergent life forms in climatically similar areas would be that at different times and places in the history of evolution, the organisms got separated from the mainstream of life, and continued to evolve independently—in their own way.

Physiological Evidence

With the knowledge gained from the earlier sections it would have become clear to you that many biochemical processes are identical in almost all organisms. For example, every organism—whether it is fish, frog, snake, cockroach, moss, fern, bacterium, or rose—obtains the energy for its life processes through reactions that constitute glycolysis and Krebs cycle. The enzymes taking part in these reactions are also the same in all living things. Again, every organism contains the same master chemical—DNA—into which all the hereditary characteristics are packed. It is quite logical to conclude from these considerations that all life is basically one, and has gradually diversified in different directions. Several other instances of physiological closeness, indicating the descent of a large group of organisms from a common stock, can be cited. The form, growth and certain activities of most plants are controlled by hormones. The auxin extracted from one plant, say wheat, is also effective in any other kind of plant, say rose, pea or poppy.

Closely related plants and animals often contract similar diseases. Thus cereals like wheat, barley and oats are attacked by the rust fungus, *Puccinia graminis*. Poliomyelitis or infantile paralysis also attacks the monkey which is believed to have a common ancestry with man. These and many similar observations regarding the biochemical functions of plants and animals are difficult to explain except on the basis of evolution.

Popular Misconceptions about Evolution

Although the principle of evolution is now well established, its acceptance intially faced extreme reluctance of people from all walks of life. This was partly because of the profound influence of religious dogmas. Men were used to thinking that the whole world had been created almost at the same time, in a short period of just six days. On the contrary, the evolutionary viewpoint regards the world in the process of perpetual creation through gradual changes in the existing forms. This idea led to many misconceptions, a few of which persist even today. Some people thought that to believe in evolution was to deny the existence and authority of the Creator. This is, however, far from the truth. Evolution, and for that matter science as a whole, does not deny the existence of the hand of the Creator; it simply suggests that the method of the Creator is evolution.

Many people think that evolutionists want us to believe that man is a direct descendent of apes—gorillas and chimpanzees—and monkeys. This is expressed in popular language by catchy phrases like 'Man came from the monkey'. Cartoons depicting Darwin as having the body of a monkey and the head of his own were published in the newspapers of those days. Much ridicule was inflicted on Darwin for vividly bringing out one of the fundamental themes of biology. Such erroneous beliefs result from a careless reading of Darwin's famous book, 'The Origin of Species', and from a misunderstanding of how evolution operates. The evolutionary principle says that, except in rare instances, one form of life cannot be ancestral to another form if both are existing at the same time. On the same principle, man is only believed to have come from an ancestral stock which is now extinct, and from which apes and monkeys might have also evolved on a separate line. Thus, evolutionists do not derive man from monkeys, but only regard man and monkey to have evolved side by side, perhaps from a common ancestral stock.

SUMMARY

There have been two theories regarding the presence of living organisms on this earth. According to the first, i.e. the theory of special creation, all organisms originated in the same form in which they are seen today. The second theory, called the theory of organic evolution, maintains that the present-day complex forms have arisen from originally simpler forms through gradual but continuous changes. In other words, there has been a gradual unfolding of living forms from the earlier, simpler forms. The process is taking place even today, and will continue into the future. Although several biologists arrived at the evolutionary principle, the credit for presenting the theory with supporting evidences goes to Charles Darwin.

The theory of organic evolution has gained support from several types of studies. Fossil records show that the organisms preserved in very ancient rocks were structurally much simpler than those preserved in later rocks. The various evolutionary changes that resulted in the coming up of present-day horse have been convincingly demonstrated from fossil specimens unearthed from the various layers of rocks.

Morphological evidences of organic evolution come from the presence of homologous and vestigial organs, and from inter-grading forms.

The possibility of classifying plants and animals on the basis of similarities and differences could only have been a consequence of evolution.

The embryological evidence is based on the similarities in the early stages of embryos of one kind of animals to the mature forms of animals of a lower rank.

Other evidences for evolution include those from the geographical distribution of plants and animals, from physiological studies, and from plant as well as animal breeding programmes.

QUESTIONS

1. What do you understand by organic evolution? Why don't we call it just evolution?
2. What are fossils? Describe the formation of any one type.
3. What are the five geological ages into which the history of life on the earth has been divided?
4. Describe the stages of evolution in the horse.
5. What do you understand by homologous organs? Give five examples.
6. With the help of a couple of familiar examples prove that the domestication of animals and cultivation of plants by man have affected evolution.
7. Mention some popular misconceptions about organic evolution. How will you prove them to be baseless?
8. Describe in a common man's language the main premises of the theory of organic evolution.
9. Some students confuse the problem of the origin of life with that of its evolution. Explain in a few sentences the difference between the two problems.
10. Which are the two most direct evidences for evolution? Elaborate any one of them.
11. Some 'educated' people advocate special protection for the monkeys on the grounds that these are our forefathers. Bring out the fallacy of this argument.
12. Would you regard evolution as a fact, a theory, a hypothesis, a doctrine, a principle, or a concept?
13. Distinguish between progressive and retrogressive evolution. The evolutionary tendencies in man are supposed to be progressive in some respects and retrogressive in others. Give two examples of each.
14. Almost all books on biology give long lists of evidences in favour of evolution. Can you think of any evidence which goes against the theory of evolution?
15. Did Darwin originate the idea of evolution? If not, what was his great contribution to it?
16. Explain how the age of a rock is estimated.
17. Name at least six vestigial organs of the human body. What function might each of them have had in our ancestors?
18. What does it mean when we speak of 'a primitive organism', 'an advanced organism', 'simple plants', 'a highly specialized animal', 'lower plants' and 'higher plants'?

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CHAPTER 52

Mechanism of Organic Evolution

THAT evolutionary changes have been going on in living organisms is now established beyond all doubt, but different views have been expressed regarding how these changes might occur. It is likely that more than one mechanism is operating simultaneously, or that some particular mechanism is operative under a given set of conditions. We shall now look into the chief theories that have been put forward to explain how evolution takes place. Of these the first is now definitely disproved, but is mentioned here because of its historical importance. Its author, Jean Baptiste Lamarck, a Frenchman, deserves credit for bringing out the idea of evolution even before Darwin did so, but his arguments in support of the theory have been shown to be untenable.

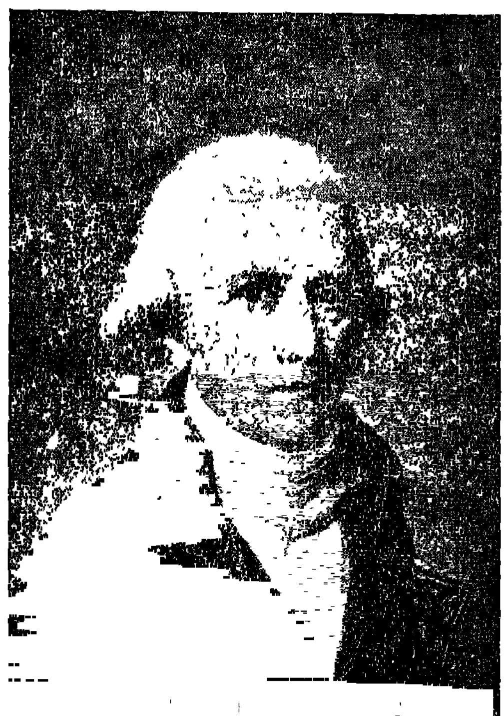


Fig. 52.1. Jean Baptiste Lamarck (1744-1829), the famous French biologist who explained the origin of new species on the basis of his Theory of Inheritance of Acquired Characters. His theory was not supported by subsequent researches. Courtesy of the Department of Botany, University of Delhi.

The Theory of Inheritance of Acquired Characters

Lamarck proposed this theory in the year 1809. He attached much significance to the striking effect of environment (water, soil, light, etc.) on the growth and form as well as the general vigour of plants. Plants, he believed, had a profound capacity for adapting themselves to changes in the environment. As an example he mentioned that the plants growing in shallow streams

('amphibious' plants) produced dissected leaves on the part of the stem which was submerged in water, and entire leaves on that outside water. Lamarck surmised that some of the adaptations of plants were passed down to the progeny. To account for evolutionary changes in animals, he introduced two basic ideas: (i) the **use and disuse of parts** lead to structural changes, and (ii) the **acquired characters** can be inherited. Lamarck believed that if a particular organ was used very extensively, it became enlarged or otherwise more useful. On the contrary, if an organ was rarely used, it gradually became smaller and smaller, or even disappeared. By such differential use and disuse of the body parts, animals gradualy became changed and acquired individual variations. These **acquired variations**, Lamarck believed, are heritable and pass down to the offspring. This idea was apparently quite appealing, and Lamarck cited many examples of how new species might arise by this method. Thus, he said that if a land animal were forced to go into a pond in search of food, it will be required to spread its toes in order to support itself in water. As the result of such stretching, the skin at the base of the toes would enlarge. The offspring of the animal would inherit this characteristic and since they would themselves also continue to spread their toes, there would be a further stretching of these. After continuous stretching in a number of generations the toes would ultimately form webbed feet. Another interesting instance of the inheritance of acquired characters elaborated by Lamarck was the acquiring of a long neck by the giraffe. As you have read in Chapter 28, the giraffe's long neck is helpful in browsing on the leaves of trees. Lamarck suggested that the ancestors of the giraffe had a small neck, and used to feed on small herbs. When the herbs became scarce the ancestral forms were obliged to browse on the leaves of trees. In attempting to reach them they had to stretch their necks. Later on when the lower branches had been eaten away, the animals were forced to stretch their necks still further. Thus, after continuous stretching, the change became substantial, resulting in an extraordinarily long neck as seen in present-day specimens of this animal.

If you remember what you read in Chapter 50, you can readily see that Lamarck was not correct in his interpretation. It is true that an organism can acquire many new characteristics in its lifetime in response to the conditions in which it lives. But the acquired qualities end with the individual; they are never passed down to the offspring. You would further recall that the parents' contribution toward the offspring is effected through the gametes, and that the potentialities of the offspring are governed by the genes contained in the nuclei of the fusing gametes. The environmental influences affecting the organism's body normally do not affect the genes, especially the genes of the reproductive cells. Since only a change in the genes can be transferred to the offspring, it is impossible that the acquired variations of the body may have a chance to appear in the offspring. A German zoologist Weismann conducted a famous experiment to disprove Lamarckian theory. He cut off the tails of a set of rats at birth, and continud this operation for 20 successive generations. When he discontinued the operation in the 21st generation, he was surprised to see the rats developing full-length tails. Thus, even 20 generations of disuse of tail did not lead to the loss or even reduction in size of the tails in the offspring. You can think of many familiar examples of the similar type. In certain Hindu families it is a custom to pierce the ear lobes of infants. This has been going on, in some families at least, for the last 200 years, but never a baby is known to be born with pierced ear lobes. Similarly,

a plant growing in poor soil may be stunted, and may produce flowers and fruits when it has only a few leaves on it. It acquires this unusual growth in response to bad soil conditions, but if the seeds from this plant are placed in proper soil, they produce normal plants.

Darwin's Theory of Natural Selection

Besides clearly formulating the theory of organic evolution with sound evidences, Darwin also developed a theory about the mechanism of evolutionary changes. Darwin was born in the year in which his predecessor, Lamarck, postulated the theory of acquired characters. In 1837 at the age of 22, when he just came out of the university, Darwin undertook a long journey for five years in the capacity of a naturalist on a British Warship, 'Beagle', which was setting out for a survey of the entire world. During this journey Darwin made innumerable observations on living organisms and collected a large number of specimens from various parts of the world, especially South America and Australia. As mentioned before, Darwin was impressed by the small variations found in the same species of plants and animals from different places. On returning home from his 5-year voyage, he worked on his field-notes and collections for 20 years and arrived at certain generalizations. The value of Darwin's work does not lie in the mere collection of voluminous information and innumerable specimens; it lies in the fact that from such simple observations he produced fundamental and novel results about the proof of the occurrence of evolution, and elaborated a theory about its mechanism. He noted that living objects show innumerable variations some of which are heritable and that many new varieties of plants and domestic animals have been produced by man by introducing small changes into them (by hybridization) followed by a selection of the desirable types. It occurred to Darwin that selection similar to that exercised by man might also be operated by Nature and that this natural selection may be bringing about the evolutionary changes in the characteristics of living things. Darwin happened to read an essay on population by a well-known economist, Malthus. He had suggested that the human population increases much faster than its food supply, and that natural catastrophes like famines, diseases, floods and accidents keep the population in check.

Now let us see how Darwin fitted this background to evolve his 'Theory of Evolution by Natural Selection'. Darwin's theory consists of three parts: First, variations are constantly taking place in organisms; many of these are heritable. Although small and inconspicuous to start with, the variations gradually become large and prominent. Only the favourable ones among them tend to accumulate during the course of time; the less favourable get eliminated. Secondly, most organisms produce a much larger number of offspring than can possibly survive. Since the amount of food, nesting places and other requirements of life are limited, there is a severe competition between them for these essentials of life. In the face of this competition for survival (the so-called **struggle for existence**) only those organisms that are most fitted in life can survive and transmit their useful characteristics to their offspring. The third premise of Darwin's theory was this: Since Nature exercises a selective action, somewhat similar to that of a breeder, on the most favourable variations, the species would gradually evolve to become better adapted to the conditions of life.

At the time when Darwin was elaborating his theory another naturalist, Alfred Wallace,

working thousands of miles away, independently reached almost the same conclusions. It was a strange chance that just about the time Darwin was preparing to publish his results, Wallace sent him a summary of his theory of evolution. It was an unpleasant surprise for Darwin to see that Wallace's views were very similar to his own. Thinking that he might be accused of an improper utilization of another person's work, Darwin decided to keep back his own essay and to let Wallace publish his results and get all the credit. However, at the intervention of some very close and influential friends Darwin published his report jointly with Wallace in 1858. In 1859 Darwin elaborated his theory in the form of a book entitled 'Tendency of Varieties to Depart Indefinitely from the Original Types by Means of Natural Selection.'

Some aspects of Darwin's theory have been misinterpreted by people, especially those engaged in popularizing science. Just what is meant by the phrase: **'Survival of the fittest'**? It is common to hear this phrase in everyday life in referring to those who become the masters of a situation, leaving their competitors behind; or in connection with those who show a distinct superiority over others in physical strength, efficiency in doing their daily routine, capacity for pleasing their seniors or even for exploiting and tricking others. However, this is fitness only in the general affairs of life. Fitness in the biologic sense and in the sense in which Darwin used it is the success in producing offspring to continue the species. The course of evolution is not determined by the socially successful individuals, but by those who are able to reproduce their kind. Of course, it often happens that an organism that is 'fit' in the general sense is also fit in the biologic sense, but this need not always be so. Consider, for instance, the mule. It is sturdier than either of its parents—mare and donkey—and it can live through adverse conditions of life with greater ease. In short, it is quite fit so far as its own life is concerned. But it is sterile. It can leave no offspring, let alone any contribution toward the evolution of new varieties of mules. The important thing to remember is that evolution counts on biologic fitness—fitness to produce a larger progeny—rather than on fitness in the wordly sense. Let us consider an example from human affairs. In general the rich and highly educated people leave fewer children than the poorer and illiterate. From evolutionary point of view, therefore, the poor and less qualified people are fitter than the other class. The poor are winning the struggle for life; the rich are successful in the struggle only for cash and accomplishment.

Darwin's theory had several weak points, e.g. Darwin had no clear answer for the origin of variations in Nature. At times he was inclined to believe in Lamarck's theory of the inheritance of acquired characters. Perhaps no one could have given any precise explanation; the time was not yet ripe for it. The solution to this and several other problems had to wait for discoveries in other subjects, especially cytology and genetics. You would recall that although Mendel had published his principles of heredity in 1866, his work lay neglected till the year 1900. Our present understanding of this subject is largely a gift of the twentieth century.

However, subsequent work in various disciplines of biology has not only furnished the much-needed experimental proof of Darwin's postulates, but has also extended them. With some modifications Darwin's premises evenly fit into the observed facts of biology, and Darwinism, or let us call it **neo-Darwinism**, has come to stand as the most acceptable mechanism of evolution.

We shall presently see how it ties in with the observed facts.

Darwin had said that there is a limitless variation in the population of every kind of organism. A moment's reflection would show you that this is indeed quite true. Think of the numerous varieties of mangoes in our country; each one of them is different from the other. Variation is in fact widespread in the population of every species of living organisms. As said before, the fact was already well known, but Darwin gave it a special significance when he said that variations play an important role in the evolution of species and that they represent stages in the transition of one form into another. Although Darwin was not able to account for the appearance of heritable variations, today we know that the sexual method of reproduction allows for a limitless variation in the organisms.

You would recall reading in Chapter 50 that during the formation of gametes there is a random segregation of chromosomes, and there is an equally random union of gametes at fertilization. Due to very heterogenous combinations of chromosomes in the zygote, the resulting organism is almost always slightly different from its parents as well as its brothers and sisters. These variations are the main-spring of **speciation**, or the origin of new species. Variations may in turn allow still more random chromosomal combinations. These changes go on till the offspring becomes noticeably different from the original parents.

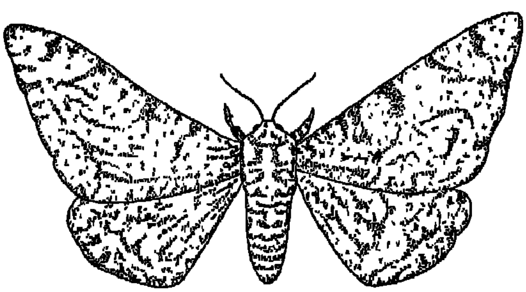
Variations may also come about due to mutations. Since these form the basis of another theory about the mechanism of evolution, we shall take it up later.

The second premise of Darwin was that the organisms have a tendency to produce a large number of offsprings. One tobacco plant, for instance, may produce as many as 400,000 seeds. If all the seeds from even one generation of tobacco plants were to get a chance to establish themselves, there would be no place even for all of them on the earth. This is also true of organisms like the elephants which reproduce only once in 10 years. It has actually been calculated that a single pair of elephants would bring forth as many as 19 million elephants in 750 years.

With the coming into being of such large numbers, the offspring naturally has to struggle for proper conditions of life. Besides the limited overall resources of food and space, several other factors may become important for the survival of a species. For example, if a plant has no effective mechanism for seed dispersal, it would shed all its seeds in its vicinity. The seedlings of such plants may become so crowded that almost all of them die. This is so true of the domesticated maize plant that it could hardly survive without human assistance. At other times natural enemies or diseases may wipe out a species completely.

Darwin had presented fairly convincing evidence for evolution and for natural selection by correlating his observations on living plants with those on fossils. There was, however, no method available for observing natural selection in the field or in the laboratory within a short time. That is because evolution of new forms in Nature is so slow that it takes hundreds or even thousands of years for the transition to become recognizable. However, in the years following Darwin some striking cases of natural selection, effective within a short period, were brought to light. In certain experiments involving the use of organisms with short life cycles, it became possible even to see natural selection in the laboratory. We shall relate a couple of such instances here.

A curious instance of natural selection of a moth was recorded in Great Britain. The peppered moth (*Biston betularia*) occurring in Great Britain had two forms—light and dark (Fig. 52.2). In the early part of the nineteenth century (1830s) only the light form was present; the dark form was rarely, if ever, seen near towns. The light coloured moths were found on tree trunks covered with lichens where it was hard for birds to see them, and thus they escaped death. Due to the development of industries in the neighbourhood of cities, the lichens were killed, and the tree trunks became black due to the deposition of industrial soot. Birds that prey on moths could now see and peck at the light coloured form against the dark background of dead lichens; however, the dark, scarce moths escaped death. In the course of nearly 50 years they completely replaced the light coloured moths, so that now only the dark coloured moths are found near the cities.



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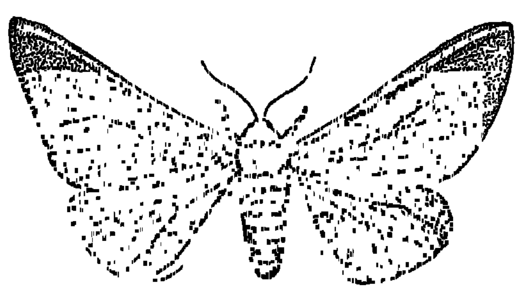

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Fig. 52.2. The light (A) and dark (B) forms of the peppered moth (*Biston betularia*). The dark moths matched the colour of the tree trunks and escaped the birds that preyed on them. From J. Fisher, J. Huxley, G. Barry, and J. Bronowski, *Nature*, a part of the Macdonald Illustrated Library and published by Rathbone Books Limited, London, 1960.

A remarkable experimental evidence came from work involving the use of DDT on flies and other insects. It had been seen that when spraying of DDT was continued for several years in a certain locality, the flies stopped responding to the insecticide. Had they developed resistance to DDT? Apparently yes, but acutally a different story emerged. Among the original population of flies there were certain forms that were externally similar to the other flies, but had the unique quality of resistance to DDT treatment. With the first few sprays of DDT the susceptible flies were killed. The resistant flies, which were originally present in small numbers, now got a chance to multiply rapidly, and after some time there were only resistant flies in the locality. This evidence also lends support to Darwin's supposition that in the face of competition and natural selection only the fittest will leave some progeny; the rest would perish.

De Vries' Theory of Mutation

The Dutch botanist Hugo De Vries, who was also one of the three rediscoverers of Mendel's laws, proposed the mutation theory for the evolution of new species. His theory was essentially a modification of Darwin's. Whereas Darwin visualized a series of small, gradually merging variations, De Vries established the existence of abrupt and more distinct variations. He noted these sudden variations when he was engaged in genetical studies of a species of the evening primrose

(*Oenothera lamarckiana*). He grew many generations of these plants and sometimes noted the appearance of certain plants with very different flowers, leaves and general appearance. He also discovered that some of the changes were inherited by subsequent generations. Certain of the new types were distinct enough to be considered new species. To this phenomenon of the sudden appearance of a heritable change De Vries gave the name mutation. The new plants were called mutants. De Vries extended his conclusions to evolution, and said that such mutations could be responsible for the appearance of new species in Nature. Later work showed that the changes in the appearance of the primrose actually resulted from changes in the chromosomes themselves. This explained why these changes were heritable. It has been estimated that in Nature a gene may mutate once or at the most twice during one million cell divisions. This would apparently mean that mutation in any individual in terms of a particular gene is a very rare phenomenon. However, this low figure becomes significant if you consider the long time that elapses before a species changes into another. During this time, ranging from a few hundred to a million years, an unlimited number of individuals of a species are produced. And if to these facts you also add the fact that each individual has thousands of genes in it, the total changes that might occur due to mutations become still more significant.

How many mutations will change a species into a new one? No one knows the answer, but a provisional guess suggests that 600 to 900 mutations would be enough. It becomes obvious from this estimate that it would require a very long time—may be several thousand years—for a new species to be established. However, under suitable experimental conditions one can actually see new species coming up within a short time. This was beautifully demonstrated by the American geneticist H. J. Muller. He exposed the cultures of fruit flies to X-rays. The flies were maintained in the laboratory for several years during which many new types of flies sprang up in the progeny. Some of them were indeed so different that if one did not know their ancestry, it would be difficult to place them among the original flies.

The Formation of New Species

We have to explain one more point before leaving this discussion, namely, how the numerous species of plants and animals have actually arisen. This can be explained partly by the presence of varied habitats to which the organisms adapt themselves. Differences in the habitats have come about due to the many changes that have taken place in the climate of the earth. However, this does not explain the presence of scores of species of fishes, of flies or of cucumbers inhabiting the same strip of water or land. We have indicated previously that the differences between individuals also come about due to a random segregation and recombination of genes in the process of sexual reproduction, and due to mutation. However, even these mechanisms by themselves would not normally form new species—they can at best create differences or variations in the same species. Let us stop to see how. The members of any given species are breeding between themselves and as the result of this their genes are being constantly re-assorted and recombined. If the rate of reproduction is quite high, any new variation would soon become uniformly distributed in the population. The variation due to the occurrence of occasional mutations would also become distributed throughout. If the mutation happens to be recessive, the chances of its free expression would be further reduced. Thus we see that the mechanism

of variation can contribute but little to the formation of new species unless a part of the population becomes separated or isolated from the rest, so that there is no interbreeding and free exchange of genes. New forces of natural selection then induce the separated parts of population to change radically and to evolve along independent lines. To start with, the isolated populations are similar. As thousands of years of isolation roll by, the two sections of the population become less similar to each other and eventually become so different that they can no longer interbreed, and are then considered new species. There are three main kinds of **isolation**. The population of a rapidly reproducing species may become so large and widely spaced that a section of the population at one end of any area may never come in contact with the remaining section at the other end. The formation of new rivers, islands, mountain ranges, etc. may also isolate parts of the population and make interbreeding impossible. Isolation may also be brought about by the different times of flowering of two plants, by different feeding habits and hence the difference in the places frequented by two kinds of animals, or by preferential living in certain conditions. Thus isolated, the parts of the population gradually evolve into new varieties and then into new species. The various races of man are believed to have originated as the result of geographical isolation. With modern means of transport these barriers are soon breaking down and an intermixing of races is taking place fieely, so that the differences between them are tending to disappear. The second kind of isolation is genetic in which the two kinds of organisms fail to produce viable and fertile offspring.

The Biologist's View of the Living World (Phyletic Evolution)

You are now adequately educated to look at the living world with the eye of a biologist. It is important to emphasize once again that the stream of life flowing throughout the multitude of plant and animal species is the same; that none of the organisms, not even man, was specially created in its present form, but that each kind has developed from much simpler types through gradual changes, accumulated over billions of years. There are too many gaps in our knowledge of the story of life because of the enormous time during which the various events have taken place. Nevertheless we can get a fair idea of the course of events by piecing together the scanty observations.

According to the best available estimates the first forms of life, whatever their nature, arose some five thousand million (5,000,000,000) years ago when there were extensive oceans over much of the world. We need not repeat here our speculations about the nature of the very first forms of life—they might have been like coacervates or like the present-day viruses—instead, we come straight to the stage when well-organized cells had come into existence. These cells were, in all probability colourless, and derived their nutrition from the inorganic salts present in the surrounding water. The free-swimming cells acquired all possible forms that a single-celled body is capable of attaining. Some of these forms were quite like the protozoans that we see today. As time went on, varying numbers of certain kinds of unicellular members took to living together and moving as a body, often with a division of labour, thus establishing the colonial habit. The colonial forms might have later organized into multicellular animals somewhat akin to the present-day sponges. Hand in hand with these changes in form, certain unicellular creatures developed chlorophyll which enabled them to prepare their own food. At this stage the organisms were not distinguishable into

plants and animals. *Euglena* (p. 59) and certain other similar organisms are reminiscent of some of those self-sufficient organisms which have rightly disregarded the exclusive claims of either the botanists or the zoologists. It took nearly four thousand and five hundred million years for life to evolve to this stage of development.

In the early part of the next era (Palaeozoic) the green colonies of cells gave rise to multicellular algae which further evolved into many kinds of small and large seaweeds. The colourless colonial organisms developed into invertebrates. The oceans then teamed with invertebrates of many kinds—sponges, corals, jellyfishes, snails, brachiopods (clam-like animals with shells) and arthropods. A very common arthropod of that era was a swimming crustacean called trilobite (Fig. 52.3). Fossils of many species of trilobites have been unearthed, but none of these exists today (we speak of them as having become **extinct**).

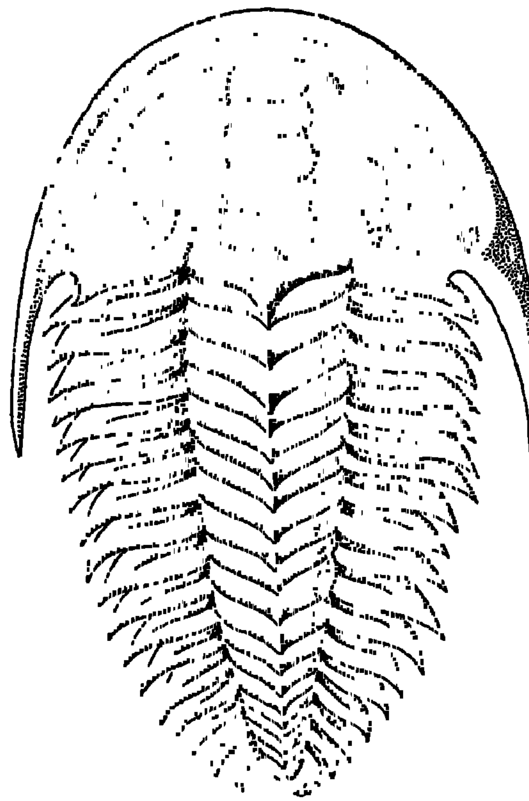

Fig. 52.3. A fossil trilobite. This crustacean was abundant in the Palaeozoic era. From M.E. Hogg, *A Biology of Man*, Heinemann Educational Books Ltd., London, 1962.

Nearly 425 million years ago plants started migrating to land. They spread first to the swampy shores where the seaweeds growing on rocks might have managed to survive when the sea water receded. Later on plants spread on to the higher land areas. Some of the land-invading plants remained small, and became only partly independent of the aquatic medium. They also developed the capacity to grow on almost bare rocks where the soil, and hence the mineral matter, was meagre, and water was available during only a part of the year. This line of evolution resulted in the appearance of liverworts and mosses. A second line of evolution of the first land flora resulted in plants which had needle-like or fern-like leaves, and attained the stature of trees. Most of them reproduced by spores, but some reproduced by seeds. We call them seed-ferns. The hot and moist climate of that period supported a very luxuriant growth of these plants, and the land became covered with vast forests of them (Fig. 52.4).

There are good evidences to believe that after the seed-ferns and their contemporaries had become abundant, some 280 million years ago, there were sudden changes in the earth's climate which wiped out most of the forests. We see the remains of these forests today in the form of huge coal deposits or coal beds. The survivors of the fern-like stock gradually evolved into cone-bearing plants—the gymnosperms.

Let us now resume the story of animal evolution. From among the vast abundance of invertebrates there appeared the first vertebrates in the oceans. These were some kind of jawless fishes which fed upon tiny aquatic organisms. From these evolved an infinite variety and abundance of fishes. The most notable of them were the so-called lungfishes which developed an air-bladder. This organ helped them in breathing when the pond water dried up. Along with lungfishes there developed the lobe-finned fishes. These had fish-like tails but their fins had a bony frame-work somewhat like the limbs of the amphibians. Their air-bladder had changed into lungs. Most lobe-finned fishes or coelacanths, as they are also called, have become extinct except for a rare marine fish *Latimeria chalumnae* (Fig. 52.5) which was discovered in 1938 from the Indian ocean off the east coast of South Africa. From these perhaps developed the salamanders—the first amphibians. The widespread establishment of green plants on land was a significant event; it meant an abundance of food and shelter on land. This was a suitable stage for the animals to leave water and inhabit land. The first to do this were the amphibians mentioned above, and some arthropods such as scorpions and spiders.

As millions of years rolled by, new kinds of amphibians were evolved; some of them were as much as six metres long. They became the most dominant form of animal life, coinciding in time with the abundance of forests of seed-ferns.

With the climatic changes and the consequential dwindling of the seed-ferns referred to earlier, there was the appearance of reptiles. The first of these were much like the present-day alligators.

Fig. 52.4. A pictorial representation of a forest as it might have appeared in the coal-forming period of the Palaeozoic era. Courtesy of the Chicago Natural History Museum, Chicago.

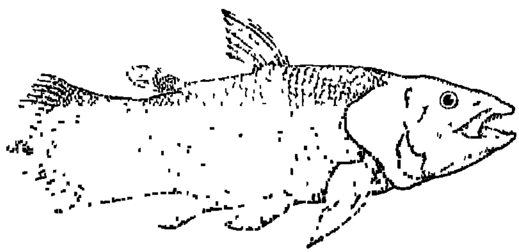

Fig. 52.5. *Latimeria*—**a living fossil. This lobe-finned fish was believed to have become extinct about 70,000,000 years ago, but was caught alive in 1938 off the east coast of Africa. Note that the fins arise from limb-like stalks and not directly from the body. This fish is thought to form a link between the fishes and the amphibians.** Courtesy of the Department of Zoology, University of Delhi.

We have covered the story of life up to a point in time which is 230 million years before today. Geologists have arbitrarily fixed this point as marking the end of the Palaeozoic era and the beginning of the Mesozoic era. The latter covered the period between 230 and 63 million years, and witnessed the reptiles becoming a much diversified and dominant group of animals. These included the turtles, snakes, lizards and the most important of them all, the dinosaurs. Some of the dinosaurs, as mentioned in Chapter 26, were the largest land animals of all times. Certain kinds of smaller reptiles evolved into birds and mammals towards the last part of this era. As stated in Chapter 27 the earliest known bird is *Archaeopteryx*. It was of the size of a crow, and had characteristics of both birds and reptiles. It is considered a connecting link between the reptiles and the birds.

On the plant side, this period first showed an abundance of gymnosperms and then their decline, corresponding to the drastic changes in climate. Simultaneously some stocks of ancient plants evolved into the first flowering plants or angiosperms. In the last 63 million years, which mark the Cenozoic era of the history of life on earth, there has been profound diversification and dominance of mammals and flowering plants. The herbaceous plants among the angiosperms, and man among the mammals, both of which arose only a million years ago, dominate the earth today.

This, then, is the broad picture of the world as conceived by a biologist. The phyla of existing plants and animals represent, though in a modified way, the stages through which some of plants and animals may have evolved over the past ages. This means that when a given species forms a new species through evolution, all the members of the group do not change over to the new species. A certain percentage of them undergo only minor changes. They do not change as fast as those which have entered the 'stream of transition'. In course of time these 'go slow' members appear distinctly outmoded or primitive in comparison to the fast evolving or advanced members. The primitive groups continue to live so long as they can suitably adjust themselves to the environmental influences. If they outlive their environment they slowly dwindle, become highly restricted in their distribution, and finally cease to exist. In other words they become extinct. There have been some curious findings in man's quest into the story of life. It happens that certain organisms which are supposed to have become extinct since long and which are known only in a fossil state are suddenly discovered by some one to be living unchanged in one corner of the earth. Such organisms are called **living fossils.** *Metasequoia* (found wild in central China) among plants, and *Latimeria* (lobe-finned fish) among animals are examples of living fossils.

SUMMARY

Enough evidence has accumulated to strengthen our belief in organic evolution. However, regarding the forces bringing about evolutionary changes, there has been more than one view. According to Lamarck's theory of acquired characters, the environment around an organism has profound effects on its shape and organization. The use or disuse of parts can also bring about modifications. Lamarck adds that acquired characters are heritable. However, numerous scientific experiments and genetical studies suggest that this is not possible.

According to Darwin every organism produces offspring much in excess of the number which can actually survive. This results in severe competition among the members of the same or different species. Only such members as can stand the competition survive; the rest perish. Nature exercises a selective action in the survival of the species. Although in Darwin's days there was no method of observing evolution in field or laboratory, subsequent biological studies have brought to light many such instances.

At times sudden changes in the genes of reproductive cells lead to the formation of a new variation in Nature. The phenomenon is known as mutation. These variations can be inherited. Mutations followed by isolation of the species, leading to a new line of development, may be a strong force in evolution.

QUESTIONS

1. What do you understand by the phrase 'survival of the fittest'?
2. Suppose that acquired characters could be inherited. Would it have been good or bad for us?
3. Mention some examples, other than those given here, to support the belief that acquired characters cannot be inherited.
4. What are the main points of the theory of natural selection as proposed by Darwin? How has this theory been modified after Darwin?
5. How do new variations arise in Nature?
6. What are mutations? Look up several instances of natural and induced mutations.
7. What is the role of isolation in evolution?

FURTHER READING

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CHAPTER 53

Organisms in Relation to Their Surroundings

EVER since your first acquaintance with biology in Chapter 2 you have learnt many things about living organisms—the structure of their bodies and the way they function, the places they usually inhabit, the way they behave and reproduce, and so on. We shall now join many of those bits of information to get an insight into some of the general principles of life. It may well be that you have already inferred these principles, but it would be helpful to recapitulate them here.

The Biosphere

In our attempt to have a new look on the world of life as a whole, let us first ask: How far below the surface of the earth, and how far above it do living organisms spread? It may surprise you to know that although the earth's atmosphere extends above to nearly 1,600 kilometres, no more than six kilometers are inhabited by living organisms. About 95 per cent of the organisms live below or at sea level—in marine water, in fresh water, on land, and on or inside the bodies of other organisms. In the sea, living organisms have been found as far deep as seven kilometres. Thus the maximum spread of living forms is just 13 kilometres, and this is known as the **biosphere**.

Some biologists have rightly described the biosphere as the **web of life**. They visualize that all organisms are related to or are associated with one another just as every thread of a spider's web is connected or related to every other mesh, closely or remotely. The web of life is a well organized and delicately balanced system—changing constantly and yet maintaining its individuality. Each kind of plant and animal of this web has a distinct role to play in the balanced continuation of the web. At times this balance may get disturbed, but if left to itself it soon attains an equilibrium. Any disturbance sets a chain reaction of compensating adjustments till the equilibrium is reached once again.

Food Chains and Food Webs

Now let us see how this biosphere or web of life is maintained. In this are present many green plants which capture the sun's energy and use it to build the living stuff—protoplasm—from common elements derived from air, water and soil. Then there are plant eaters or herbivores which convert the vegetable matter into flesh. The plant eaters serve as the source of food or energy for the smaller of the flesh-eating animals. The smaller animals serve as food for the larger animals, which in turn are eaten by still larger ones, and so on A series of

organisms, that are directly linked with one another because of eating or being eaten, form a **food chain**. Even those organisms which have no natural **predators** are killed by parasites to keep their numbers in check.

The starting point in a food chain is always a green plant. Now the whole of the plant material cannot be converted into flesh of the herbivore. Much of the vegetable matter cannot be used or digested by the animal and is excreted. Again, a kilogram of the flesh of a herbivore does not make a kilogram of the body of the carnivore which preys upon it. At every stage only a part of the energy stored in food can be utilized to build new protoplasm. This also means that a certain number of organisms would provide food for a much smaller number of organisms of the next higher series. If we were to reset the food chain of figure 40.1 (p. 443) to show the numbers of organisms at each level, the diagram would assume a pyramidal shape. In terms of energy the higher one goes up a chain, the less the energy that becomes available. From the standpoint of utilization of energy, therefore, the fewer the links in the chain, the more efficient is the food chain.

Since many animals eat more than one kind of food, the food chains are seldom simple and isolated; often several chains overlap and interconnect with each other. This results in the formation of **food webs.** One such food web is shown in figure 53.1. Not all the connections have been shown here. Many complications in the chains occur due to the attacks of pests, parasites, etc. Upon death all creatures, big and small, become the food of saprobiotic organisms (beetles, flies, bacteria, fungi, etc.) which decompose the dead bodies, and return the constituent elements to the air, water and soil. You will recall that in Nature there are operating cycles of carbon, hydrogen, oxygen and other basic requirements of life. We call them cycles because the atoms of some of the elements are being used over and over again. All these cycles make possible the continuation of the biosphere.

No One Stands Alone

Any disturbance in the web of life may have serious consequences, either in the region of disturbance or even in a remote and seemingly unconnected part of the biosphere. The following examples would make it clear. At one time the man-eating tigers of Andhra Pradesh suddenly became a big menace in many parts of the Ganjam district. At the first consideration, it may surprise you if we say that the calamity was traced to the activities of some unscrupulous traders. The evil events caught on to one another somewhat as follows. The forest pig and deer, which constitute the natural food of the tiger, were killed in large numbers by a group of unscrupulous traders. The tiger could now obtain very little of its natural food, and was forced to cattle-lifting and finally to man-eating.

A somewhat opposite kind of disturbance was created in Madhya Pradesh due to large scale hunting and shooting of the tiger and other large carnivores. Freed from their natural enemies, the deer and pigs multiplied so enormously that their plunders made the growing of crops around forests almost impossible.

These examples should serve to illustrate the interdependence of organisms, and of the factors of environment. The modes of dependence are fully known for some parts of the biosphere; for some other parts they are still unknown, but biologists take the existence of relationships for granted. For good reasons biologists often contend that no man stands alone in the world, howsoever self-sufficient and sophisticated he might claim to be. Indeed little do most people realize

how closely their lives are linked up with tiny insects, crawling earthworms and millions of invisible bacteria.

If you have become aware of the existence and operation of the web of life, you will not look upon an animal, say a cat, as

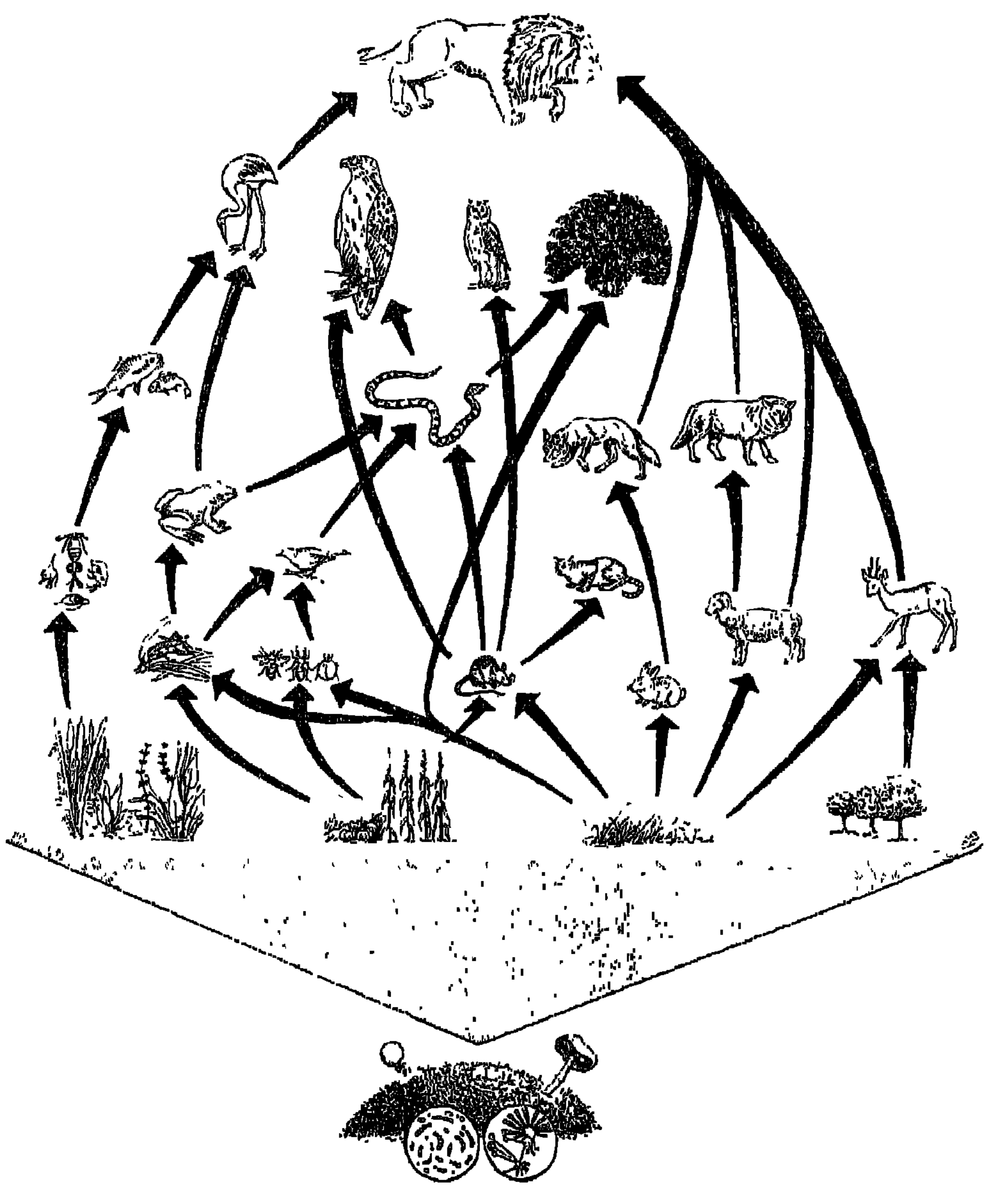


Fig. 53.1. A food web showing the main food links. Note that the starting point of each food chain is a green plant. When the animals eat more than one kind of food and are preyed upon by more than one species of predator, the food chains become interconnected and form a food web. Ultimately the saprophytic organisms—bacteria and fungi—decompose the dead bodies, and release the constituent elements into the air, water and soil.
Courtesy of the Department of Botany, University of Delhi.

merely a cat. The appearance of a cat will bring to your mind many more things, first of all its role in the overall scheme of life. Think of a neighbour's family whose members have little sense of cleanliness. They may let heaps of dirt collect in and around their house. The dirt may become the breeding pool for houseflies. The latter may carry germs of some deadly disease and deposit them on the food in another house whose members may contract the disease. Imagine further that most of the patients succumb to the disease. The grief-stricken survivors may try to forget their grief, at least temporarily, by taking such things as 'bhang' and opium. The chances are that they eventually become addicts. Suppose then that the government decides to stop the free sale of opium. The addict will go to any length to get his dope, and in this process he may become a criminal. Do you see how an unhygienic house-hold has caused the disastrous end of another family? Perhaps you find this example too far-fetched; nevertheless, it does show the interdependence of one organism upon another.

Habitats and Communities

Another fact would also become quite obvious: Organisms are not haphazardly scattered on the earth; most of them live in rather chosen places. A place where the conditions for the existence of an organism prevail is known as the **habitat** of that organism. Let us put it in an another way. The habitat is the place to which an organism's peculiarities of structure and function are best suited for life under the existing conditions. Thus the habitat of the frog is a pond, lake or stream; the habitat of *Marchantia* (a bryophyte) is moist shady surface; that of the elephant is dense forests such as those found in Assam and Nilgiris; the habitat of the lion is Gir forest (in Gujarat); that of the earthworm is moist soil; for the mosquito it is marshy areas, and so on. It is easy to see that, in general, none of the habitats is limited to just one locality or one region of the world, but it is distributed widely. For instance, marshy areas occur in many parts of the world, and almost all of them are infested with mosquitoes. The area that contains or encompasses all the habitats of an organism is known as the organism's **range of life**, or simply the area of its distribution. Thus, the range of life of the rice plant covers all tropical countries; that of wheat is spread over all temperate lands; the range of the frog and most other amphibians extends to the moist temperate and tropical parts of the world, and so on.

Any habitat would generally support more than one form of life. A stream, for instance, is not inhabited by frogs alone; several other kinds of organisms—fishes, water plants and water insects—also live in it. Thus the habitat as well as the range of occurrence for several kinds of organisms may be very nearly the same. Similarly some foot-hills of the Himalayas appear at the first sight to be covered with 'sal' forests, but the hot, moist climate and rich soil of that habitat does support a large number of other plants also. In addition, many animals also find food and shelter in the forest.

The plants and animals of any given habitat—a pond, a forest, a grassland, a desert—are not simply living in the same place by chance; they are bound together by many inter-relationships, of which the food chains are the most important. A group of different species of plants and animals living in a habitat is called **plant-animal community** or **biotic community**. The activities of the members are in some way helpful to the continuation of the

community as a single, integrated unit. The biotic communities are generally named after the most important or conspicuous plant species.

As stated already, most communities are integrated or self-sufficient units. A community comprises the **food producers** or green plants; the **primary consumers** or herbivores; the **secondary consumers** or carnivores, and the scavengers such as bacteria and fungi which prevent any undue accumulation of dead organisms and which help to release the organic elements back to the atmosphere. Quite often, the members of the community are victimized by specific kinds of parasites. The entire population is so adjusted in the food chains that the appearance and composition of the community remains within definite limits with respect to the numbers and kinds of various organisms.

The communities which we have been talking about are natural communities, i.e. they are free from the influence of man. In addition to these there are also artificial or man-made communities. A field of corn or any other crop is a familiar example of such a community. In between the crop plants, several kinds of weeds, grasses, algae and many small animals make their homes. The composition of an artificial community is dictated by man; that of a natural community by the undisturbed interaction of natural conditions.

The Environment

It is a common experience that organisms from one kind of habitat will not survive or succeed if they are transferred to a different kind of habitat. To cite a common example, the fishes which live in sea water will not survive if they are brought to fresh water. The converse is also true. Here is another example. The tea bushes which flourish in the moist, cold valleys at higher altitudes (as those of Assam) will not thrive in the hot plains of the Punjab.

Studies on the distribution of plants and animals bring out another important fact, namely, every living organism is greatly dependent on the conditions which prevail in its habitat. This dependence has resulted in the development of certain appropriate characteristics (we call them **adaptations**) which make the organism better suited to live in a certain kind of environment. Thus fish, which have taken to life in water, have fins as well as gills. The cacti, which are adapted for existence in dry places, have soft tissues that store large quantities of water, and a thick cuticle which considerably reduces the loss of water from the plant. The conditions under which an organism lives constitute its **environment**. It is a complex of **physical** or **abiotic factors** such as light, temperature, humidity, pressure, etc.; and living or **biotic factors** comprising all the other living organisms (especially those living in the vicinity). While the environment exerts a profound influence on the organisms, at the same time the organisms also bring about changes in the environment. There is thus a reciprocal relationship between the organisms and their environments. The study of these two-way relationship between the environment and the organisms is known as **ecology** (Gk. *oikos*=house-hold; *logos*= discourse) and biologists specializing in this branch of study are called ecologists. Ecology includes in its scope the study of all physical and biological phenomena controlling the living organism. It teaches us the wise use of our forests, crops, rivers and animals.

The various factors exert their effects together, all at the same time. Not only

that, they even interact among themselves. For that reason no single part of the environment can be considered without taking into account the other factors. However, for understanding the operation of the environment, we shall study these factors one by one.

Temperature

There is a wide variation in the temperatures prevailing on the surface of the earth, and accordingly, most organisms are exposed to this variation. The fluctuation in temperature is comparatively much less in water than on land, and it is the least in the oceans.

Most organisms have a specific **optimum range** of temperature in which they can live most successfully and comfortably. For instance, man can work actively when the temperature is around 25C (although this would actually depend on the amount of water vapour in the atmosphere). In addition to the optimum range, there are also upper and lower limits of temperature tolerance—usually between 0C and 50C; beyond these limits organisms cannot live at all. Consequently we find that the living creatures are most abundant in places where the temperatures do not go beyond these points.

The limits of tolerance are by no means universal; there are many exceptions to this generalization. For instance some bacteria can survive at a temperature as low as —240C. On the upper scale, some bacteria are known to withstand 120C for a few moments, but none can withstand such a high temperature for even half an hour. You would recall here that in all bacteriological work the media are sterilized by heating them in steam at 120C under high pressure. Some blue-green algae regularly live in hot springs at 87C. However, these are only exceptions; most living things cannot stand temperatures higher than 50C. Death at higher temperatures occurs due to changes in the proteins and fats, the two most vital compounds in the cytoplasm.

It is naturally not possible to speak of an optimum factor for any process unless other factors are also defined. For example, one experimenter found that when the concentration of carbon dioxide in the air was 0.03 per cent, the optimum temperature for photosynthesis of a potato plant was 20C. When the concentration of carbon dioxide was increased to 1.2 per cent, the maximum rate of photosynthesis was obtained at 30C. Thus both 20C and 30C are optimum temperatures for photosynthesis, depending upon the concentration of CO_2—another factor of the environment. Let us take a more familiar example. We have said that man feels comfortable when the temperature of the air is around 25C, but this is true only when the relative humidity is 50 per cent. If the relative humidity decreases to 15 per cent he would feel cold at 25C. On the other hand, if the humidity becomes 90 per cent, he would feel warm and uncomfortable at the same temperature.

Although temperature cannot by itself be considered to be the most important factor, sub-optimal levels may have a marked effect on the functioning of the organism. Most biochemical processes have a Q_{10} of 2, that is, within limits, an increase of 10C doubles the rate of the process. Some effects of changes in temperature are easily observed with the naked eye. Thus, ants run faster in summer than in winter; the eggs of some fishes hatch in 7 weeks when maintained at 0C, but in just one week at 15C. The house cricket chirps at a higher rate (more chirps per minute) in summer than in winter.

Temperature is the most obvious factor of the climate of any area. The main climatic

zones of the earth are differentiated primarily on the basis of the prevailing temperatures. Thus a very hot and winterless zone is **tropical**; a hot zone with a cool winter is **subtropical**; and a zone with warm summer and pronounced winter is **temperate.** The zone with a short summer and a long severe winter is **alpine.** Although India lies largely in the tropical belt, due to its lofty mountains it experiences all kinds of climate. Thus the climate is temperate to sub-temperate in the Himalayas, tropical in Western Ghats and Assam, sub-tropical in major part of India, and alpine at the higher altitudes in the Himalayas.

Temperature and moisture exert an important influence on the distribution of plants and animals on the earth. In our country, for instance, there are nine well-marked zones of plant life (floristic regions), each with its distinct vegetation (Fig. 53.2). The zonation of plants due to varying temperatures is particularly striking in the Western Himalayas which include Nainital, Mussoorie, Simla and Kashmir. There is a steady fall in temperature with increasing altitude, and a corresponding change in the kind of vegetation (Fig. 53.3). Taking only the chief forest types into consideration, we find that 'sal' (*Shorea robusta*) forests are spread in the tropical and sub-tropical zone, up to 1,524 metres. Higher up, in the temperate zone extending to 3,657m, 'sal' becomes scarce and extensive forests of conifers and broad leaved trees take their place. In the lower elevations of this zone, 'chir' (*Pinus roxburghii*) is common; it soon gives place to 'deodar' (*Cedrus deodara*) and blue pine (*Pinus walli-*

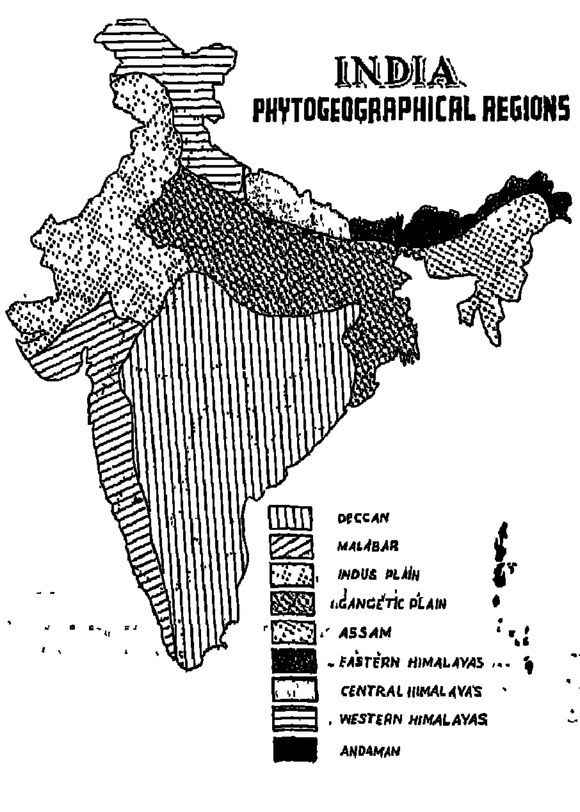
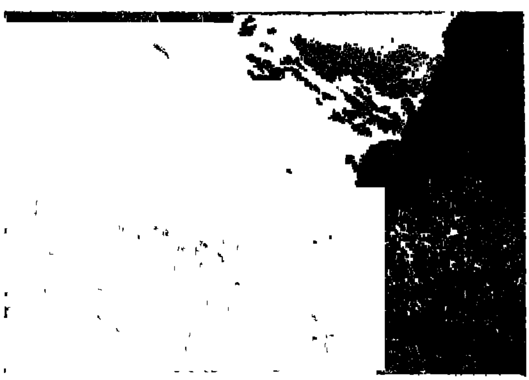


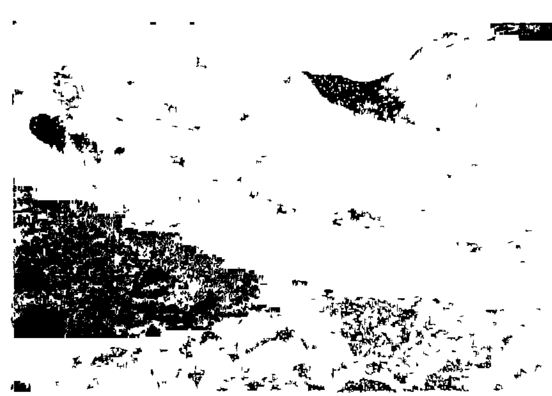
Fig. 53.2. On the basis of prevailing conditions of temperature and moisture, the country has been divided into nine phytogeographical regions. Courtesy of the Department of Botany, University of Delhi.

A



B

Fig. 53.4. Alpine vegetation at 3650m in Central Himalayas at the entrance to valley of flowers. Note the stunted growth of plants—*Birch* and *Rhododendron*. The green patch in C is *Rhododendron*. In the background is Mt. Rataban. Courtesy of the Department of Botany, University of Delhi.



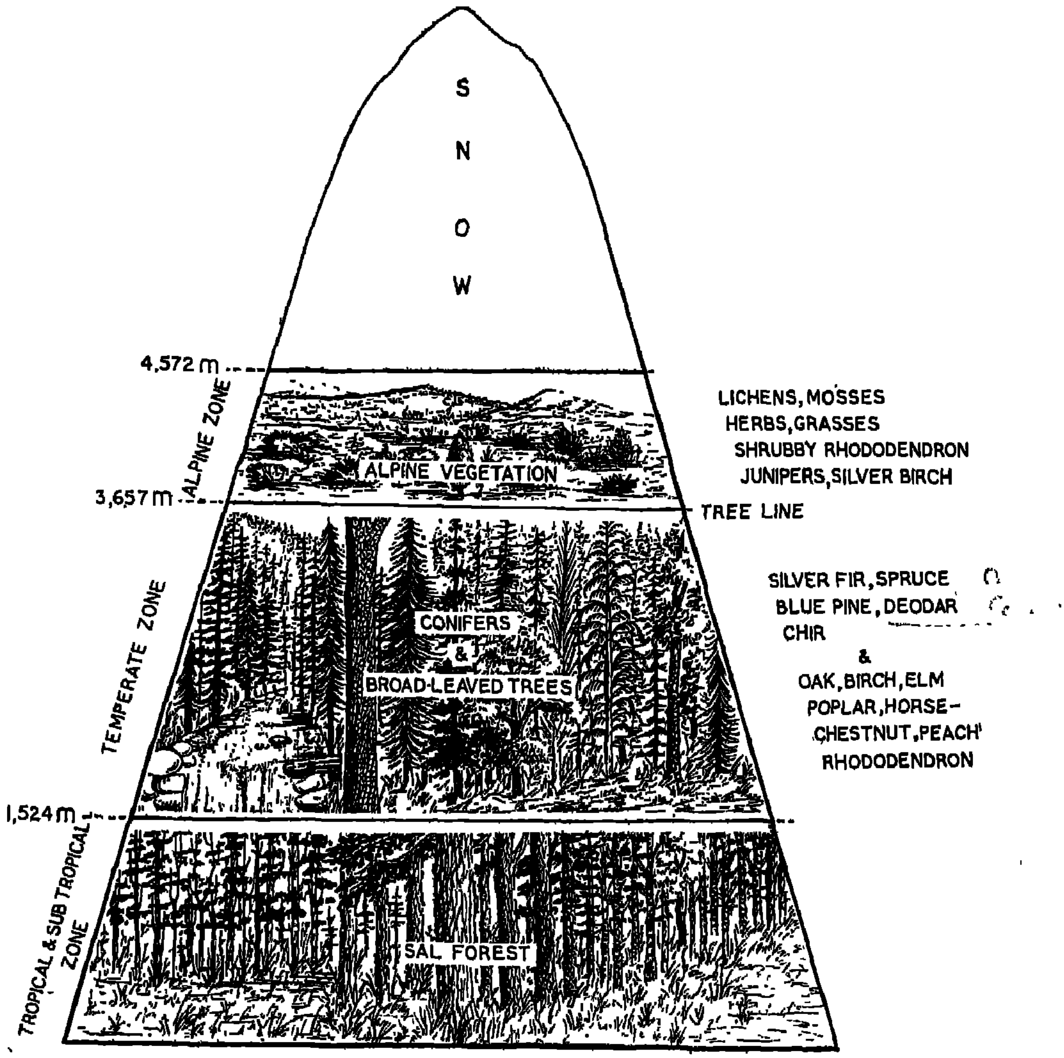


Fig. 53.3. Diagrammatic representation of the zones of vegetation in the Western Himalayas. Temperature is the major factor delimiting the various zones. Only a few of the representative plants have been shown in each division. Courtesy of the Department of Botany, University of Delhi.

chiana). Further up, spruce (*Picea* [illegible]) and silver fir (*Abies pindrow*) form extensive forests. The broad leaved trees comprise species of oak, poplar, horse-chestnut, elm, pear, *Cornus* and *Rhododendron*. The upper limit of the temperate zone (altitude—3,657m) marks the **timber line** or **tree line**, since above this, in the alpine zone (3,657-4,572m), large trees are totally absent. The lower range of the alpine zone is characterized by the presence of much stunted plants such as high level silver fir, silver birch, juniper and shrubby rhododendrons (Fig. 53.4). In the upper part of the alpine zone, herbs, grasses,

mosses and some algae constitute all the plant life. At elevations above 8,000m even these plants become scarce, and finally one finds nothing but the snow-covered peaks.

Several other examples of the limiting influence of temperature on the distribution of organisms may be mentioned. The polar bear has adapted itself to life in regions where the temperature is always below the freezing point. Its thick coat of fur and a layer of fat below the skin are partly responsible for its success in colder regions and failure in the tropics. Its food habits put a further restriction on its movement since its food (seals, young walruses, fishes, etc.) is available only in the polar region.

The spread is again determined by the prevailing temperatures. The malarial parasite fails to develop in the body of the anopheles mosquito if the temperature is below 25C. This explains why malaria is prevalent only in the tropical marshy regions; in temperate areas it is not so widespread. Of course, if the parasite gains entry into the body of a man, it may persist in his ever-warm body until his death.

While some organisms are limited in their distribution by the annual average temperature, others remain restricted because of their inability to withstand very low or very high temperatures even for a short while. Guavas and several other tropical fruit trees would be simply wiped out if freezing temperature prevailed for more than a week. The banana reacts to unfavourable temperatures in another way. This plant occurs naturally in warm regions; it can also be grown in cold regions, but there it produces either no fruits at all or very small ones. In colder regions, therefore, the banana is grown only as a curiosity in glasshouses.

Since the occasional exposure to extremes of temperature at one time or the other is almost inescapable or unavoidable for most organisms, they have evolved mechanisms that enable them to survive in spite of their brief exposures to extremes of temperature. The commonest adaptations comprise the decrease of water content, the conversion of most of the free cell water into its bound form, and increase of salt concentration. The latter tends to decrease the freezing point of water. Thus most seeds, spores and cysts (such as those of amoeba and some bacteria) can withstand temperatures much below the freezing point because they have very little free water to freeze. The loss of water also imparts the capacity for resistance to high temperatures.

Some animals effect a temporary change of behaviour to overcome the extremes of temperature. Thus frogs, certain reptiles, insects and molluscs undergo a winter sleep or hibernation in caves, burrows or crevices in the rocks. As said in an earlier chapter, during hibernation most of the physiological activities such as respiration and heartbeat, are reduced to the barest minimum—in some animals to just five per cent. Certain insects, spiders, molluscs and mammals undergo a state of dormancy during summer (estivation). In this way they not only avoid the high temperatures outside but also save on food material.

Light

The importance of light as the basic source of energy for the synthesis of carbohydrates in photosynthesis has already been dealt with in detail and needs no further comment. Light is also essential for the synthesis of chlorophyll. However, to serve as the source of energy is not the only role of light; it influences life in a number of other ways too. Some of its important roles in plants are shown in Fig. 53.5. Through these

effects light may determine which types of plants and animals will live in a particular area.

The visible part of the sun's radiation is composed of seven colours, namely, violet, indigo, blue, green, yellow, orange and red. The blue and red colours of the spectrum are useful in photosynthesis. Beyond the violet region are the ultraviolet rays having several physiological effects such as the decomposition of auxin, the formation of pigments in animal cells, and irritation of the retina as well as other light receptors. On the other side of the spectrum, beyond the red region, are the infra red rays which are chiefly responsible for the heating effect of light.

Although light is apparently abundant on the earth, its quality and intensity vary from place to place. It may therefore become a determining factor in the distribution of organisms. In a dense forest, for instance, the crowns of the trees often form a thick cover, or canopy, and allow very little light to reach the ground below. Between the forest floor and the tree canopy, therefore, one can see one or more strata or stories, each comprising only such plants which can thrive in the kind of light received

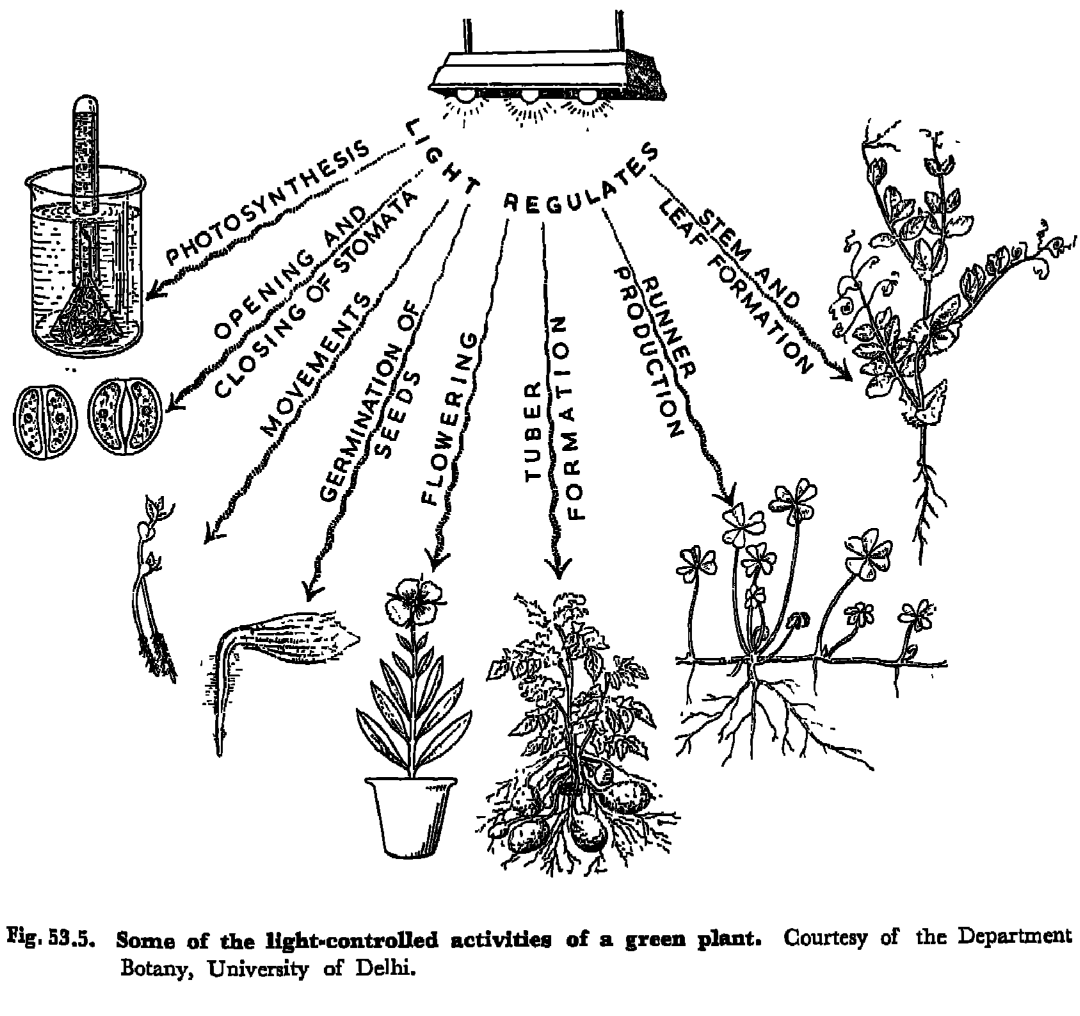


Fig. 53.5. Some of the light-controlled activities of a green plant. Courtesy of the Department of Botany, University of Delhi.

there. The plants requiring fairly strong light must reach very near the crown of the trees. Such plants are generally climbers since only these are able to reach the canopies. Besides the climbers there are small trees, shrubs and herbs which require comparatively less intense light. On the floor of the forest the intensity of light is very low; one finds only shade-loving plants such as liverworts and mosses, or saprophytes which do not carry on photosynthesis.

The **stratification of plants** in response to light is still more marked in the oceans. Here the extent of penetration of the light determines the maximum depth at which green plants may occur. Up to a certain depth below the surface of the sea there is good penetration of light; this region abounds in green plants, chiefly algae. About 70 metres below the surface plant life becomes very sparse and comprises chiefly the brown and the red algae. At a depth of about 200 metres no more than one per cent of the total light is available, and therefore auto-trophic plants are absent. This has an indirect effect on the distribution of sea animals. Those which subsist entirely on green plants are not found in deeper waters. The carnivores can however live here, since they eat other animals which are smaller than themselves and which come up to the zone of green plants. The ocean floor has only **saprobionts** (plants and animals which live on dead organic matter) and carnivores.

The differential distribution of organisms noted above results from the unequal amounts of available light. Plants may be further restricted in their distribution, due to the relative duration of day and night. As said in Chapter 46, some plants grow and reproduce only when the critical photoperiod is provided. Depending upon this requirement, plants are grouped into three kinds—short-day, long-day and day-neutral or indeterminate. As you would recall, long-day and short-day plants can grow successfully only in those regions of the world where the requisite photoperiods prevail. They cannot successfully extend their ranges beyond a certain latitude. This knowledge is useful in importing plants from one country to another. For example, if a floriculturist in Madras imported a garden plant from a country like Canada, the chances are that he would simply be disappointed since the plant is unlikely to flower under the day lengths prevailing in Madras. Of course biologists can make a plant produce flowers by growing it in experimental chambers in which the photoperiod can be varied by providing electric lights, but this is not possible on a commercial scale.

Although not widespread, the phenomenon of photoperiodism also operates in some animals. The migration of certain birds is believed to be particularly controlled by the photoperiod. Certain insects are known to reproduce only under appropriate photoperiods.

The chief direct use of light to most animals is the perception and awareness of the surroundings. If you recall the various groups of animals studied in Section 3 you would come to see that there are many kinds of light receptors in the animals. In the lower forms such as *Euglena* and in the flat worms the light receptors are mere pigmented spots which can distinguish light and dark areas; in the higher animals there are definite image-forming organs of different kinds.

The behaviour of certain animals is clearly influenced by the degree of their tolerance for light. Most of the common animals that you see around can tolerate bright light and move about freely in daytime. There are others, such as the earthworms and

termites, which cannot stand intense light. They live in their burrows during the day, and come out at dusk, or earlier if it is cloudy. They have a predominantly nocturnal life. Imagine what funny things these habits would mean. It is likely that two species of animals, of which one is active in daylight and the other during the night, may be inhabiting the same spot and yet never meet each other throughout their lives!

We can frequently recognize structural modifications developed in response to variations in available light. A good general idea can be had by comparing a shade plant (**sciophyte**) and a light-loving plant (**heliophyte**).

Light-loving plant	*Shade-loving plant*
1. Internodes short.	1. Internodes elongated.
2. Leaves small.	2. Leaves large.
3. Mechanical tissues and xylem well-developed, parenchyma not abundant.	3. Mechanical tissues and xylem poorly developed, parenchyma abundant.
4. Leaves thick and dark green, with palisade on one or both sides, spongy tissue scanty, stomata smaller, fewer and entirely on the lower surface, chlorophyll content high, vein islets small.	4. Leaves thin, delicate and light green, spongy parenchyma copious, stomata larger, numerous and on both the surfaces, vein islets large, intercellular spaces large and abundant.
5. Water content low.	5. Water content high, sometimes associated with succulent habit.
6. Osmotic pressure high.	6. Osmotic pressure low.
7. Flowering early and profuse.	7. Flowering delayed or completely checked, not so profuse.
8. More hardy, resistant to drought and parasitic infection.	8. Less hardy, susceptible to drought and parasitic infection.

Soil

Soil is a basic requirement for all land plants in two important ways: It holds in an available form, water as well as the mineral salts needed by the plants and it provides a foot-hold or anchorage without hindering the growth and aeration of the roots. Because of these important functions the soil often determines the kind and vigour of the plants growing in a particular climatic region. Even a farmer knows that the type and quality of his crops depends, in the first place, upon the type of soil in his field.

Let us then first see what soil is. Most of you perhaps think of it as mere dust or dirt. Actually, however, it is much more than that. Soil is derived primarily from the breakdown or **weathering** of rocks. Depending upon the period and process of weathering the thickness of the soil on the parent rock varies considerably. However, any soil will show different layers in it on the basis of colour, chemical nature and size of

the particles. These layers are collectively known as '**soil horizons**'. Soil has five important components: Mineral matter, organic matter, water, air, and the plants and animals living in it. A part of the mineral matter is soluble in water while the remainder is insoluble. The insoluble matter may occur as coarse particles such as sand and gravel, or as fine particles such as silt and clay. The organic matter is added to it from the decomposition of dead plants and animals by the activities of numerous micro-organisms present in the soil. Since some materials are affected earlier than others, the organic matter is in various stages of decomposition. It usually forms a dark and spongy product called **humus**. Being highly absorbent, the humus holds water and soluble minerals which would be otherwise easily washed away by heavy rain. Contrary to popular belief, the soil is not a graveyard in the sense of having no living forms. Actually it abounds in smaller forms of life, especially bacteria, fungi, algae, beetles, earthworms and snails. Many insects such as the white ants make their nests in the soil and each nest may have as many as two million individuals. The earthworms are also quite plentiful. You would recall here Darwin's observation that there may be as many as 50,000 earthworms in an acre of soil. Besides, millions of bacteria and numerous soil fungi also inhabit the soil. It is not generally realized that, space for space, there is much larger number of organisms in the soil than on it. Soil organisms play a very important part in the fertility of the soil. By their burrowing activity, the rodents, moles and earthworms, allow a lot of air to enter the soil and bring about many other changes in it. The air occupies the spaces between the soil particles and is continuous with the atmosphere outside. The presence of this soil air is very essential for the growth of the roots of all plants. It is therefore not advisable to over-water the fields, since this would drive away most of the soil air, and the growth of the plants would suffer because of the non-availability of oxygen to their roots.

Although plants are traditionally grown in the soil, the latter is not unreplaceable for their maintenance. If we can arrange for a proper supply of mineral salts, oxygen and adequate support, we can do away with the soil. This indeed has been done on a fairly large scale by maintaining what are called water cultures or solution cultures (Fig. 53.6). An aqueous solution of salts which would supply all the major and trace elements is taken in a jar or tank, and the seedlings are supported on perforated lids in such a way that the roots dip in the solution. The technique is also called **hydroponics** (Gk. *hydor*=water; *ponos*= exertion) or the science and art of crop production in liquid culture media. However, the aeration of the medium is so tedious a process that the project turns out to be highly uneconomical. The practice has, therefore, not found much favour in agriculture.

The physical and chemical characteristics of the soil—such as the sizes of the soil particles, water and air, the kind and quantities of minerals present in it, the degree of acidity or alkalinity, the percentage of humus—and the types and numbers of living organisms in it show wide variation. In any scheme of agriculture, therefore, a good deal of attention is paid in adjusting the soil to the specific requirements of the crop. The encouraging feature is that of the many factors affecting plant growth, the soil is the one which can be easily controlled.

Over the centuries plants have adapted themselves to thrive on various kinds of soil. Thus the peculiarity of any soil is often

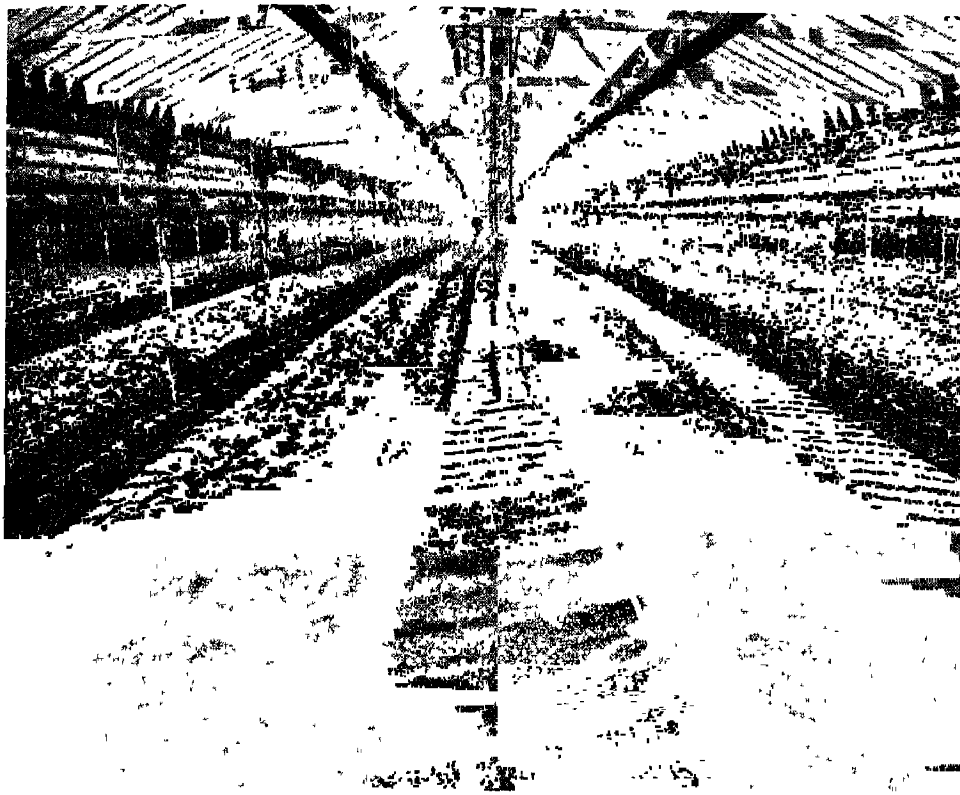


Fig. 53.6. A hydroponic (water culture) farm. The seedlings of radish are supported in such a way that their roots dip in the nutrient solution. Courtery of the U.S. Army Photograph Section.

correctly indicated by the kinds of plants growing on it. Such plants are called **indicator plants**. Thus the presence of a prostrate grass called 'dhab' (*Desmostachya bipinnata*) indicates a high salt content in the soil. Similarly, a luxuriance of 'bui' or 'lonia' (*Suaeda fruticosa*) and salt wort (*Salsola baryosma*) is indicative of saline soil (Fig. 53.7). A widely occurring plant of the saline wastelands and 'usar' land is a prickly prostrate herb called 'berkateli' (*Solanum surattense*).

Water

The failure of crops due to lack of rains, and the sparseness of vegetation due to proverbial dryness in the deserts are common place facts which show the importance of water for the growth of the plants. Equally well-known are the contrasting effects of the excessive availability of water. Thus the Western Ghats and Khasi-Jaintia Hills of Assam, which receive a heavy rainfall, are covered with dense evergreen forests. These correlations at once become understandable when you recall that in all active cells water is the most abundant constituent and its presence is essential for the functioning of all physiological processes. To take an example, nearly 5,000 kg of water go into the making of a kilogram of wheat. A good

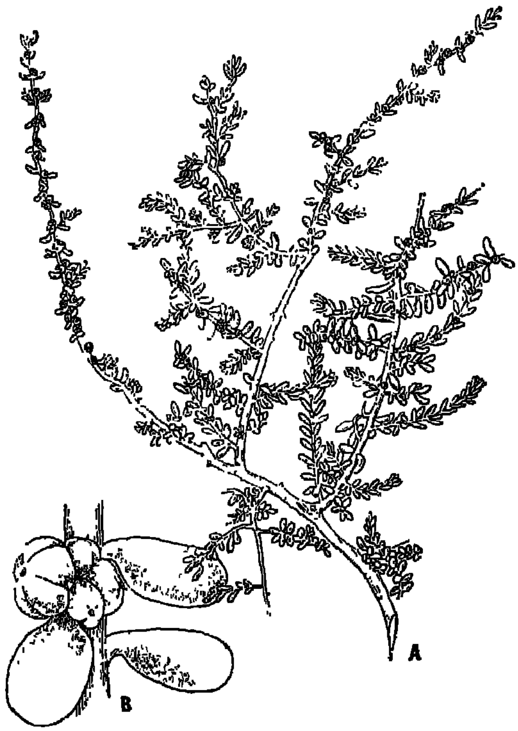


Fig. 53.7. An indicator plant, *Suaeda fruticosa*. The abundance of this plant in an area indicates high salinity of the soil. A. Branched shoot. B. Part of the shoot enlarged to show the succulent leaves and fruits. Courtesy of the Department of Botany, University of Delhi.

proportion of this amount is lost by transpiration.

Many plants and animals actually live in water, and are so adapted for aquatic life that they would simply dry out or collapse if they were kept out of water even for short periods. Many of them, such as the seaweeds, squids, some jellyfishes and whales, attain large sizes without any proportionate development of the supporting tissues. This is because water lends buoyancy to their massive bodies.

Most land plants cannot make use of surface water, but being fixed to the substrate, they must have a good supply of water in the soil. The land animals, on the other hand, are motile and therefore not quite so tied down to a watery habitat as plants. Some exceptions may, however, be pointed out. Frogs live in areas in which water is plentiful. Since the other amphibians also have a thin and pervious skin, they must frequently return to water to moisten their bodies. Moreover, water is indispensable for their reproduction: both sperms and eggs are released in the water where fertilization can readily take place. Most other land vertebrates, however, have impervious skins and can therefore live in less moist places. They can readily move to the water-source whenever they need water.

Some plants like the mosses and ferns are also necessarily confined to places where surface water is freely available for the greater part of the year or at least at the time of fertilization. Plants growing in places exposed to prolonged dry periods show many structural modifications designed to cut down the loss of water. Plants like *Capparis decidua* (Fig. 53.8) have done away with the leaves through which large quantities of water are lost. Here the stems have taken over the function of photosynthesis. The expanded cladodes of *Opuntia* have a lot of water storage tissue protected by a heavily cutinized epidermis which cuts down the loss of water considerably.

There is one more aspect that we must consider. The total amount of water in the seas and in the atmosphere is quite limited. A British scientist has estimated that the amount of moisture in the earth's atmosphere at any given time is just sufficient to cause about 2.5cm of rainfall. This water would suffice the needs of all the

Fig. 53.8. *Capparis decidua* **is adapted to live in extremely dry places. It bears small leaves but even those are shed while still quite young. The thin spiny branches of the stem are green and carry on photosynthesis.** Courtesy of C.K. Varshney, Department of Botany, University of Delhi.

organisms of the world for just 10 days! Since the world has been receiving a large amount of water in spite of these calculations, it is apparent that there is a continual circulation or cycling of the water from air to land and sea, and back to the atmosphere again through rainfall, riverflow, transpiration and evaporation. The major events of the **water cycle** are shown in figure 53.9.

Altitude and Pressure

The earth's atmosphere which is constantly pressing upon our bodies weighs about sixty thousand billion tons! This means that at sea level it exerts a pressure of nearly 1 kg per square centimetre. Our bodies are so used to living under this constant pressure that we hardly realize its importance. However, on going up to very high altitudes, as in a jet plane, one comes to recognize atmospheric pressure as an important environmental factor. Before considering the effects of pressure on living beings, let us first learn a few more things about the atmosphere.

The entire envelope of atmospheric gases is attracted towards the earth because of its gravitational force. Due to the enormous weight of the atmosphere most of its constituent gases are tightly packed near the earth's surface; in fact 90 per cent of the weight is contained in the first few kilometres. It follows, therefore, that the higher we move from the earth's surface, the less dense shall we find the atmosphere to be, and the less would be the pressure. At 5,500 metres, for instance, the air pressure is only 0.5 kg per square centimetre, and at 4,800 metres it is only one-thousandth of that at sea level.

Now it is easy to see that if a human being is suddenly transported, without any adequate protection, from sea level to a very high altitude, say 14,000 metres, his blood would literally begin to boil, since lower the pressure the lower is the boiling point of a liquid. At somewhat lower heights, say 7,000 metres, another difficulty endangers life. The concentration of oxygen is so low that not enough of it enters the blood. The result is that one starts gasping and feeling uncomfortable. To adjust to a low pressure environment mountaineers carry with them cylinders of oxygen; the cabins of the high-

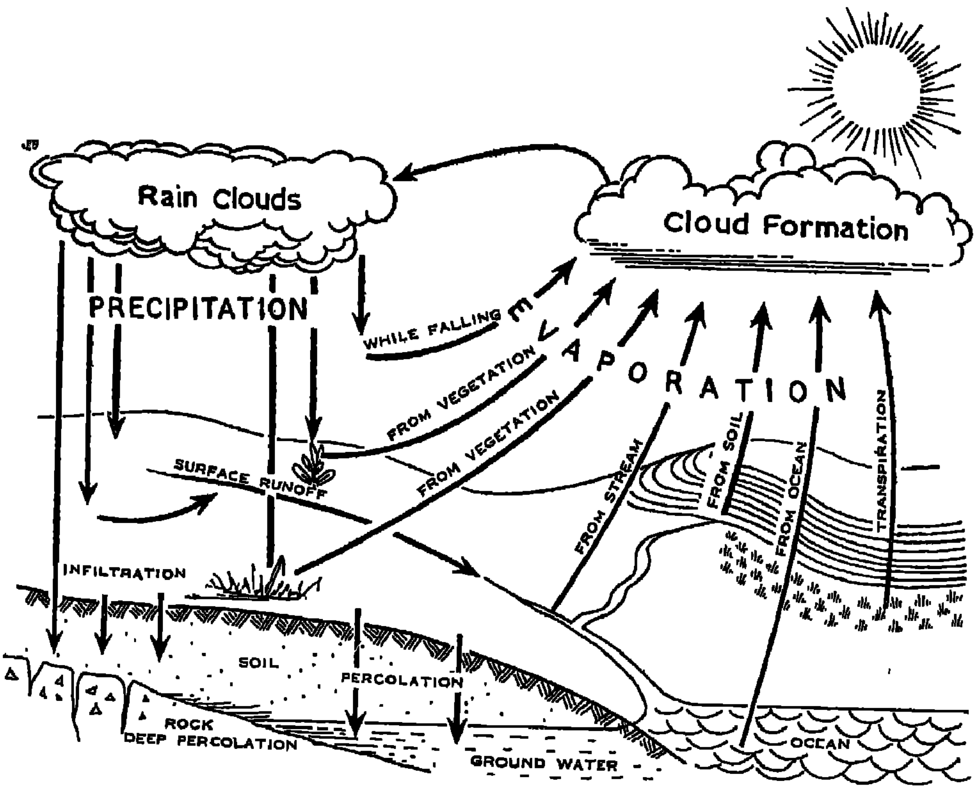


Fig. 53.9. The water cycle. Adapted from *Water: The Yearbook of Agriculture*, 1955, U.S. Department of Agriculture.

flying jet aeroplanes and the space suits of the cosmonauts are made airtight and even pressurized to keep the passengers under natural conditions.

The effects of high altitude on plants are not clearly understood. The concentration of oxygen and carbon dioxide are certainly very low. This would mean less photosynthesis and less overall metabolic activity. The presence of high winds, freezing temperatures and increased ultraviolet rays make the environment still less favourable. Due to the combined effects of these factors, perhaps, at very high altitudes plants seldom attain any large size.

Living organisms become sparser and sparser as we go higher and higher. Not only that, the number of species also becomes smaller. In the Western Himalayas, for instance, we come to the upper edge of the forests at about 3,657 metres above sea level. This edge of the forest is called the tree line. Above the tree line there are only low growing plants—mosses, lichens, grasses, herbs and some shrubs. Even such plants which are tall trees at lower altitudes, have a bushy form above the tree line. At an altitude of about 9,500 metres, the height of the Mount Everest, there is perpetual snow, and hardly any higher plants subsist there.

Like terrestrial (land-inhabiting) or-

ganisms, marine organisms, especially those inhabiting deep waters, also have tons of sea water pressing upon their bodies. It has been found that if the deep sea fishes, which are used to living under enormous pressure of sea water, are suddenly brought to live near the surface, their bodies burst into pieces.

The Biotic Factor

As said earlier, the environment of any organism is partly biologic and partly physical. Every living organism is influenced by others of its own kind as well as those of other kinds. For instance, when many members of a species are living together and when their demands become more than can be adequately provided for, there sets in a competition for food, space, light, or any other requirement. For plants rooted in the earth, this means death of the less favourably placed members. When animals face such a situation, some of them are forced to move away from their original homes. During migration they may get exposed to the ravages of other environmental factors, enemies, parasites, and so on. Only the best, the luckiest, or the quickest to adjust survive these hardships, and are left to carry on their kind. There are also many instances of the mutual influences of organisms. Here we shall consider only a few of them.

As an instance of species to species influence, we may consider cases in which the spread of one species is either helped or hindered by other species. A case in point is the spread of a straggling weed, *Lantana camara*, throughout India. It was originally introduced as a garden plant from tropical America, but has now become a serious pest as it competes with other useful plants. Its quick spread has been helped by birds which feed on its fruit and disperse its seeds widely.

A marked biotic effect is being experienced by the rapid spread of a parasitic plant dodder or 'amar bel' (*Cuscuta reflexa* and *C. hyalina*). The famous 'kadam' tree (*Anthocephalus indicus*) around Mathura district has been almost completely wiped out during recent times due to the profuse growth of the beautiful (?) thread-like yellow stems of dodder on the branches of the trees which become depleted of all food reserves and die out. Some time back there were thick stands of 'kadam', but they are now very rare.

An area of natural vegetation newly opened to grazing exhibits a remarkable interplay of biotic factors. The grazing brings about a number of changes. Plants, which are more palatable to cattle, soon become wiped out from the area. Some other plants may be eliminated just because they cannot stand the trampling of animals. The less palatable ones are then benefited by the absence of their competitors, and may grow more luxuriantly over the entire area. The dung of the grazing animals may bring about changes in the soil which may then support a different set of plants and microorganisms. The change in flora may subsequently lead to a change in the types and numbers of living organisms dependent upon the previous species. If grazing continues unchecked, the plant cover protecting the soil may be thinned out, leading to a loosening of the soil particles. Much of the upper fertile soil may then be transported elsewhere by erosion due to wind and water. The once green area may eventually become converted into a desert.

As mentioned earlier, one organism is linked with another in the relationship of prey and predator. The plants are eaten by the herbivores, the latter are consumed by small carnivores (flesh-eating animals) which are in turn devoured by larger ones,

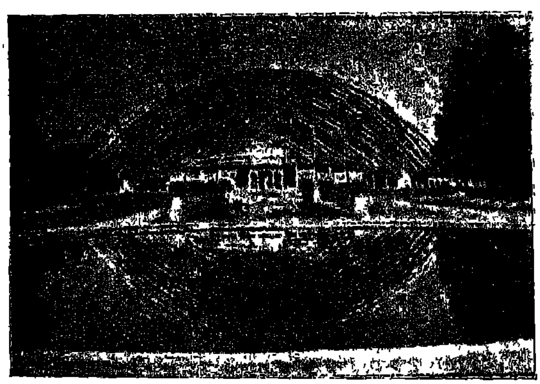
and so on. In this way every organism, except the top carnivores, has its natural predators for which it serves as food. Wisely used, the knowledge of biotic factors can help not only in keeping a healthy balance between man and Nature, but can also be used to correct a disturbed equilibrium. We shall relate here only one of the several well-known instances of the truth of this statement. This is the story of the prodigious spread and control of the prickly pear (*Opuntia*) in India. The plant was introduced into India about 1780 A.D. perhaps from the hot and dry regions of South America. Being a very prickly plant, it became a favourite for making hedges and fences around fields. This practice, together with an effective dispersal of its fruits by birds, contributed enormously to the rapid spread of the plant to many parts of the country. After some years the plant became a serious pest of garden and field in India, and its eradication posed a big problem. The ecologist's knowledge came handy at that juncture. It was found that an insect called cochineal insect, which is also the source of a dye, is a voracious eater of opuntias. In 1795 several thousand insects were imported from Spain and let loose in areas infested with prickly pears. The insect spread rapidly and devoured the plants, branch and root. In 20 years the prickly pears were almost completely eliminated from South India. Later on the insect was let loose in the Punjab and Rajasthan and within a few years large areas were freed from the ravages of the weed. This is an example of **biological control** and can be defined as the action of parasites, predators, or disease-causing organisms in restricting the population of another organism at a lower level than would occur in their absence. In other words, biological control involves the regulation of an organism's population density by its natural enemies. Insects, disease-producing germs, birds and rodents have been most used in such programmes.

Man and Environment

The factors of environment discussed in the preceding pages are only a few of the many that influence an organism. But even this brief discussion would serve to emphasize the overwhelming role of environment in the life of living organisms. It is no overstatement to say that almost all living creatures, with the notable exception of man, are slaves of their environment because they can seldom change the environment to their advantage. Plants and animals must necessarily live either in the environment in which they happen to be placed or to which they can move. Thus if the seeds and spores happen to be carried to favourable surroundings, they would germinate and produce more plants, otherwise they just perish. Most animals have the advantage of their ability to move about in order to find a suitable environment.

Man stands quite apart from other animals in his ability to change many factors of the environment to his advantage. Physically he is inferior to many animals—he can't run as fast as a deer, his eyesight is not as sharp as that of an eagle, he cannot swim as a fish can, he cannot fly as birds do, he cannot live in very cold or very hot places, and so on. But with his superior intellect he has invented such tools and instruments with which he can outdo all other creatures. He has gained mastery even on several forces of Nature. You have only to think of the jet aeroplane, steamers, radio, television, antibiotics, microscopes, telescopes, air conditioners and a host of other things which have made man the supreme being. He has even named himself *Homo sapiens*—the wise man. Most of his endeavours are directed toward understanding and controlling the

A



B

Fig. 53.10. A, B. Phytotron—a modern laboratory equipped for studying the growth of plants under controlled conditions of temperature, light and humidity. C. Interior view of Phytotron showing some aquatic plants. Courtesy of B.M. Johri, Department of Botany, University of Delhi.

C

environment. A farmer spends most of his time in providing the best environmental conditions to his crops; a zoo manager is always endeavouring to provide the zoo animals an environment as similar to their natural environment as is feasible. And the success of the farmer and the zoo manager is dependent on basing his practices on sound scientific principles. Thus we see that the scientific understanding of the influence of environmental factors is very important for the welfare of humanity. Ecologists and physiologists study these aspects by allowing plants and animals to grow in special experimental chambers in which temperature, light, humidity, and other factors can be regulated. In some biological laboratories of the world very large chambers of this kind called **phytotrons** are built. One such unit is shown in Fig. 53.10.

Ecology and the Conservation of Natural Resources

Man can change not only his own environment, but he can also improve the environment of the other organisms, both plants and animals, which may satisfy his immediate needs. However, in his enthusiasm to shape Nature to his advantage, he has often gone wrong and has destroyed the very sources which sustain all life. Centuries of concentration on immediate gains and gross neglect of the slow but irreparable damage has created formidable problems like food-shortage, floods, drought, deserts and epidemics. For the continuation of normal life these problems have to be tackled now on a national scale.

To some extent the neglect was due to the lack of scientific knowledge. For instance, till as late as the middle of the nineteenth century most people believed that the natural resources were inexhaustible—there appeared to be vast stretches of forests, there was free flow of water in the rivers and streams, and wild animals roamed in large numbers. The forests were, therefore, freely (unreservedly) cut to obtain wood and to provide additional land for the cultivation of crops. The wild animals were killed for both food and sport. Toward the close of the last century people started realizing that the so-called super-abundance of natural resources was not real, and soon man would face acute depletion of such important natural materials as soil and water. Ecologists all over the world have been looking into the matter and have come forward with the hopeful suggestion that even the present-day poor resources, if wisely used, can continue to contribute to human welfare for all time to come. The scientifically wise use of natural resources is called **conservation.** Literally it means 'to save'. In the ecological sense it means, as J.D. Black an ecologist has put it, 'the wisest use of natural resources in such a way that they provide the greatest good, for the greatest number, over the longest period of time'. In other words conservation simply means applying ecological principles for the exploitation of natural resources.

Floods, drought and erosion. Devastating floods in one season and the paucity of rains (drought) in another season have lately become a regular feature in our country. They are in part responsible for our perpetual food shortage. Let us look into the ecological diagnosis and treatment of this malady.

Floods are experienced when the river beds swell with water due to torrential rains in the uplands. If the water is in excess of what the river bed can contain, it overflows and spreads over the land off the banks. The amount of water getting into the river

is directly related with the presence or absence of forests in the **highlands**, i.e. the mountainous region through which a river passes before entering the valley. When rain falls on land covered with vegetation, say a thick forest, the canopies of the trees first of all put a sort of barrier to the downward flow of rain water. Some of the water is used up in wetting the leaves and branches. These hold up some water on their surface from where it is evaporated later. The rest flows slowly along the stems to the forest floor. The latter is cluttered up with large amounts of dead plant parts as well as the remains of dead animals. These soak up and retain large quantities of water, allowing only a part of the rain water to enter the soil below. Small, burrowing animals that find shelter in the forest make innumerable mounds and hollows which hold some moisture. As the water seeps further, a good part of it is absorbed by the roots and is eventually transpired. Finally, only a small part of the rain water flows down as surface water into the streams. Thus the presence of a thick cover of vegetation drastically reduces the quantity of water flowing into the river, and also retards its speed.

On the other hand, when land is denuded of all vegetation, the entire rain water strikes the ground directly. The finer soil particles spatter into the air. On falling back they fill and get tightly packed in the spaces or crevices between the larger particles, making the soil surface almost water proof. When there is a heavy downpour, very little water enters the soil; much of it flows down in a flood, carrying on its way the fine soil particles from the unprotected ground. The process of washing away of soil is called **soil erosion.** The fine soil or silt thus washed away by rushing waters is later deposited in the valley or riverbed when the speed of the flowing water has slowed down. As the result of this deposition the riverbed becomes shallow, and can contain much less water than before. On the other hand, the amount of water flowing into the river is considerably increased due to the absence of plant cover. This results in devastating floods. With the loss of fine soil and with very little of water percolating into the ground in the highland, no new plants can get a foot-hold. Over the decades the area becomes completely barren. The loss of vegetation also brings about lowering of rainfall and an increase in average temperature, thus creating drought conditions. In the presence of vegetation the snow melts rather gradually; with the loss of vegetation, it melts quickly and in large amounts, and thus makes the flood more severe.

The erosion of soil and prevalence of drought make the adjoining areas also agriculturally unprofitable. Poor agriculture in turn spells food scarcity and famine. The low yields of our soils, the disastrous floods and the calamitous droughts which have become our national problem No.1 are the price we have to pay for thoughtlessness or ignorance of our ancestors.

A network of dams and reservoirs—Bhakra Nangal in the Punjab, Kosi in Bihar, Damodar and Mayurakshi in West Bengal, Hirakud in Orissa, Nagarjuna Sagar in Andhra Pradesh, and Chambal in Rajasthan—have been built to store large volumes of water during the rains and to regulate the flow of water in the rivers. The stored water is also used for irrigation and for generating electric power. The dams and reservoirs are, however, only temporary measures for checking floods. In a few decades they get filled up with silt from the incoming water, and the periodic desilting of such huge dams becomes as difficult as preventing floods. The permanent solution of flood problem and the way to extend the usefulness of dams

is to once again plant suitable forest trees and grasses along the highlands. The presence of plant cover not only regulates the flow of water but also reduces the silting of the river beds and dams. The important thing to understand is that floods, drought and soil erosion are biological problems arising out of disturbance of some part of the biosphere, and demand a restoration of the natural balance.

Wind erosion. Wind is another powerful agent causing erosion of disforested and overgrazed land. It has created alarming conditions in Gurgaon, Hissar and Karnal districts of Haryana, and in many places in Rajasthan and Kutch. In the summer months, from April to July, the temperature in these areas is quite high, the rainfall is meagre, and hot winds blow with high velocity. The wind carries away the finer sand particles of the dry soil, and spread them in the nearby fields, on the roadside and around buildings.

Wind erosion is a quick process. It may displace the useful top soil, which varies from 15 to 30 cm. at various places, within a short time. The soil thus becomes much deteriorated. In deserts and along sea shore one can see thick clouds of sand being blown from one place, and being deposited at another place in the form of huge mounds or dunes. Thus the sand dunes keep on moving or drifting from one place to another, burying or otherwise injuring whatever plants might be surviving in the hot sun. The drifting sand particles gradually reach and cover the cultivated land, and render it unfit for cultivation. Thus the desert tends to march further, converting green fields into bleak stretches of sand. It is believed that the Rajputana desert has been slowly spreading to the fertile Gangetic plain. If ruthless cutting of trees continues, the entire valley may become another desert. It appears that even the Rajputana desert was once upon a time a rich forest. Reckless removal of vegetation over the centuries, and the consequent reduction in rainfall have made it a dry, useless, barren area. It is hoped that with the completion of the Rajasthan canal some part of the desert may once again become fit for cultivation.

Erosion by wind can be controlled by planting grasses and herbs on the fallow land so that the removal of soil particles by wind may be retarded. In deserts and coastal areas the moving sand dunes may be stabilized by planting suitable sand binders such as *Saccharum munja*, *Calotropis procera*, *Capparis decidua* and *Zizyphus nummularia.* These plants can grow in dry areas, and their extensive root system holds together the sand particles even when strong winds blow.

Upsets in the natural habitats. It has been the way of man to destroy or eliminate all natural things that come in the way of his attainment and progress, but in so doing he often fails to take count of the complex consequences that must follow. We have already referred to the alarming outcome of killing large herds of deer in Andhra Pradesh. We shall now cite some examples of the drastic changes in the natural habitats due to human interference.

Faced with acute food shortage, the government has been forced to bring more and more land into cultivation. In the First and Second Five Year Plans thick forests, thorny jungles, swamps and marshes have been brought under the plough. Such practices do yield short-range benefits, but the disturbances in the natural cycles that always accompany such operations do produce harmful effects. For example, many of the wild animals that found refuge in these places have been pushed to the wall.

Their natural homes are destroyed. These animals may not be of any direct use to man, but in the scheme of Nature, and therefore in the overall welfare of man, they do have an important role to play. To give just one example, with the clearing of forests, and the extensive cultivation of cereals, we have provided an unnatural abundance of food for weaver birds and sparrows. This together with the elimination of natural predators due to the clearing of forests has resulted in a menacing increase in the numbers of these birds. They have started concentrating in large numbers around the fields of paddy, jowar and bajra, and are causing considerable damage.

Forestry. Forests are important from many points of view. They yield valuable building material and a large number of other industrially important products such as gums, resins, fuel, paper pulp, and so on. Forests exert considerable influence on the climate of a region, and are immensely important for regulating the water supply of rivers. It is important therefore that these should be managed in such a way that they yield the material benefits without deteriorating. The felling of trees for commercial purposes should be accompanied by replanting of similar trees. The losses occurring due to pests, parasites and fires should be minimized. The folly of reckless removal of forests by previous generations has brought us deserts and floods; and we should see that things are not made worse for the subsequent generations. It has been estimated that for a balanced economy about 33% of a country's land should be covered with forests. In our country forests are spread only on 18% of the land. Realizing this the government has launched the Van Mahotsava scheme under which saplings of trees are planted every year at suitable places throughout the country.

SUMMARY

All the plants, animals and micro-organisms are knit together into one stable system called the biosphere in which every organism plays an important and specific role. The energy for the system is initially captured from the sun by green plants, and is transferred to other organisms directly or in steps involving one or more kinds of organisms. The series of living beings concerned in this transfer of energy (in the form of food) form a food chain. The various food chains existing in the biosphere are often interconnected to form a food web. The cycles of inorganic substances such as water, carbon dioxide and nitrogen help to keep the biosphere in a state of equilibrium.

The interdependence of organisms is not always evident or understood. This lack of knowledge often leads to grave and unpredictable consequences when man tries to tamper with any part of the biosphere for his diverse needs. Thus, artificially created increase or decrease in the numbers of one kind of organism may lead to an unpre-

cedented increase or complete disappearance of some other kind. The awareness of the occurrence of a natural balance is important for every responsible citizen

All living organisms, with the notable exception of man, can live successfully only in those places where the conditions for life are suitable. The dwelling place of an organism is called its habitat. Most habitats have conditions suitable for more than one kind of organism. The various organisms in any habitat are dependent upon each other for many things, chiefly food, water and shelter. Such a closely associated group of organisms form a community. It may be regarded as a sort of small-scale biosphere. Every community has more or less constant numbers of food producers (green plants), food consumers (herbivores and carnivores) and scavangers or decomposers (bacteria, fungi, etc.).

The conditions of life prevailing in a habitat are collectively termed environment. It includes: (i) physical factors such as light, temperature, humidity, chemical composition, pressure and altitude, and (ii) living factors comprising the influences of living organisms on one another. The environment exerts profound influence on the life of the organisms, and the latter in return affect the environment. The study of this reciprocal relationship between the organisms and their environment is called ecology.

All the environmental factors act together and at the same time; they even modify the influence of one another. In experimental studies, therefore, the effects of one factor are studied with reference to the prevailing factors of the environment. The peculiarities of structure and function developed in response to conditions of life are called adaptations.

In addition to the structural and behavioural effects, temperature, light, soil, water and altitude also markedly influence the distribution of plants and animals. The biotic factors involve both specific and interspecific interactions. The knowledge of biotic factors has enabled man to practise biological control of pests, weeds, etc. The biological control means checking or restricting the population of an organism with the help of its natural enemies.

The application of the knowledge of ecology is important for the proper maintenance of soils, food crops, forests and rivers. Many of our present-day difficulties such as food shortage, drought and floods, call for a judicious application of ecological principles.

QUESTIONS

1. No less than 15 elements have been in use by plants for millions of years. Why have the elements not been exhausted from the earth?
2. Define the following terms and give an example of each: (a) food chain, (b) food web, (c) habitat, (d) hibernation, (e) estivation, and (f) indicator plant.
3. Think of an example of the disruption of a natural food chain and its possible consequences.

4. Enumerate all the factors of the environment that affect a plant.

5. Ecologists claim that the only sure method of flood control is the planting of forests. What do you think of such a claim? Give reasons.

6. Name the principal components of soil and write a few lines on the importance of each.

7. Give two examples of changes in the environment brought about by (a) plants and (b) animals.

8. State clearly what you understand by balance in nature.

9. According to ecologists epidemics of all kinds result from the upset of natural balance. Explain.

10. How will you explain the following? The English sparrow was introduced into the USA. In a few years the sparrow became a troublesome pest in the USA, several times more troublesome than it is in its natural home.

11. Suppose you were asked to work out the food chains in the plants and animals in a small village. How will you go about doing it?

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CHAPTER 54

Different Types of Habitats

IN the preceding chapter you studied the ecological effects of environmental factors when each acts independently of the others. However, as also pointed out therein, the environmental factors in any habitat act collectively. We shall now see what special problems do plants and animals face in different habitats, what features equip them for living in a particular situation, and how they are distributed in their natural homes; in short how is the continuation of harmonious life of a community maintained.

Small variations of environmental factors create an infinite variety of habitats, but broadly habitats can be classified into two main types; the terrestrial and the aquatic. All dwelling places on land—level ground, mountains, desert, etc.—form the terrestrial habitat. The aquatic habitats comprise the freshwater and the oceanic or sea water. We shall now have a brief look at each of these habitats.

The Freshwater Habitat

Ponds, lakes, streams and rivers are examples of freshwater habitats. Unlike sea water, freshwater contains only a small quantity of dissolved salts, about one-hundredth of the amount present in sea water. Some freshwater lakes are more salty or brackish. The famous Sambhar Lake in Rajasthan is an example. Brackish lakes are poorly inhabited; a few species of blue-green algae, crustaceans and some other small animals are the only organisms found in them.

Conditions of life in freshwater. The organisms living in freshwater have to cope up with several special conditions. Water is one of the most indispensable requirements of life, and in aquatic habitats it is no doubt available in plenty. But oxygen, which is another important requirement, often becomes scarce. Oxygen is poorly soluble in water; at 15 C no more than 7 ml dissolves into 1000 ml of water. In contrast, the same volume of air can hold as much as 209 ml of oxygen. Moreover, oxygen is quite uniformly diffused in air, whereas in water the oxygen dissolved in one layer may be much less than in the other. For instance, the bottom layers of a pond may be almost totally depleted of oxygen by the intense activity of the decay bacteria.

Being denser than air, water offers greater resistance to movement of animals. This becomes easily understandable when you recall that you can run much faster on road than in a shallow pool of water. In addition, water currents also limit the movement of organisms, particularly of those that have

to move about in search of food. Fishes, frogs, and other motile animals, therefore, have streamlined, boat-shaped bodies which facilitate steering through water. Strong currents of water may tear the leaves into shreds or even uproot the plants and wash them away.

Water makes the organisms buoyant. The advantage of this property of water is obvious: Aquatic plants can attain large size without developing much of supporting tissues, and water animals can bear bodies much bulkier than what land animals can.

Water has a very high specific heat. This means that it absorbs and loses heat very slowly. Aquatic organisms therefore do not experience such large fluctuations in temperature as the land-dwelling organisms do. This is a definite advantage.

The body fluids of most animals and the

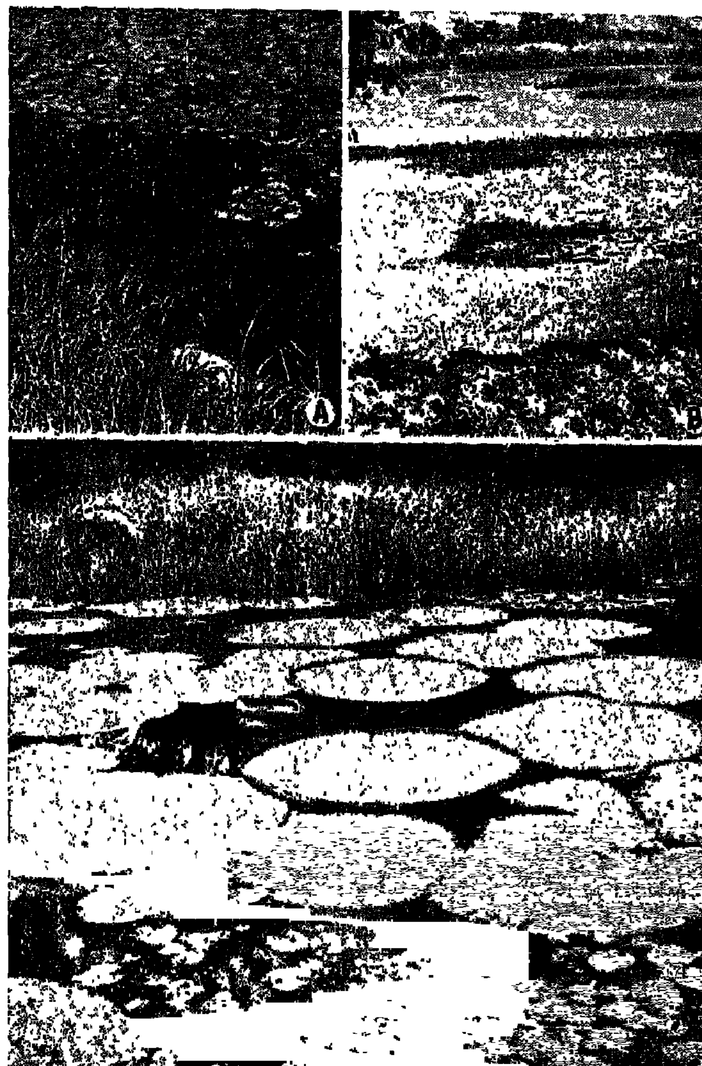


Fig. 54.1. The general appearance of vegetation in freshwater pond. Note the grasses and other rooted plants on the banks of the ponds. The open water in A is covered with *Trapa* (horn-nut); in B with *Nymphaea* (water-lily); in C with *Victoria regia* (giant water-lily). A and B. Courtesy of C.K. Varshney, Department of Botany, University of Delhi. C. Courtesy of Virendra Kumar, Delhi College.

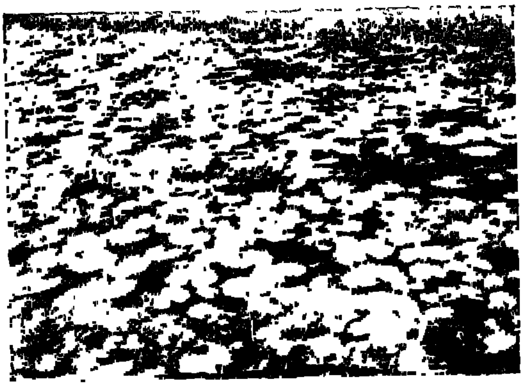
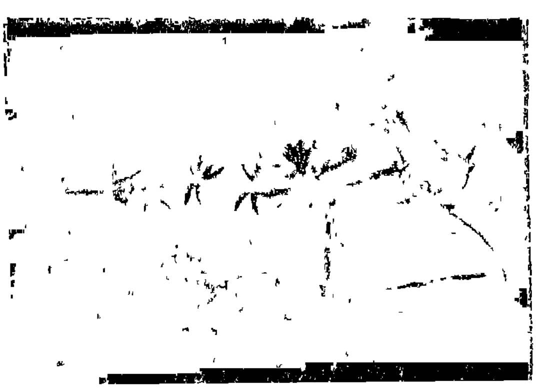


Fig. 54.2. General view of some freshwater ponds. Note the semi-aquatic vegetation on the fringe of the first two ponds. The dominant or most conspicuous plants in the ponds are ***Nymphaea nouchali*****,** ***Nelumbo nucifera*****,** ***Fussiaea repens*****, and** ***Trapa bispinosa*****.** Courtesy of the Department of Botany, University of Delhi.



sap of plants are generally more concentrated solutions than the surrounding freshwater. Large quantities of water would therefore tend to diffuse into the cells, so much so that they might burst. At the same time, some of the dissolved salts may escape from the cells into the surrounding water. The freshwater dwellers naturally have to have the facility to get rid of excess water that enters their body. They must also be equipped with suitable mechanisms for retaining the absorbed salts or for constantly absorbing more of salts.

Life in freshwater pond or lake. Perhaps the most amazing thing that you would notice on visiting a large pond or lake is that each plant and animal species occupies a place best suited to it (Figs. 54.1 and 54.2). Of course, the same species may not occur in every pond.

Near the fringe of the pond the soil is moist, though not water-logged. It is inhabited by moisture-loving plants such as *Ranunculus sceleratus*, *Polygonum plebeium*, *Scirpus*, and some grasses. Along the border of the pond the ground is swampy or water-logged. Here, *Typha* (cat's tail), *Eleocharis* (spikerush), and some tall grasses, commonly known as reeds, grow. The lower parts of these plants are submerged in the shallow water, whereas the remaining parts stand above it.

In the shallow water some floating plants such as *Nymphaea* (water-lily), *Trapa* ('singhara') and *Jussiaea repens* ('pani ki ghas') are also seen. *Nymphaea* has a strong-hold in the soil in shallow water, but extends its creeping rhizomes far into the pond. Its petioles or stems vary in length with the depth of water, and thus permit the leaves to float on water. They have large air chambers (Fig. 54.3) which make them buoyant and also help in the proper aeration of their submerged parts. Their leaves bear stomata only on the upper surface. Masses of filamentous, green and blue-green algae occur attached to the floating plants and entangled between their parts.

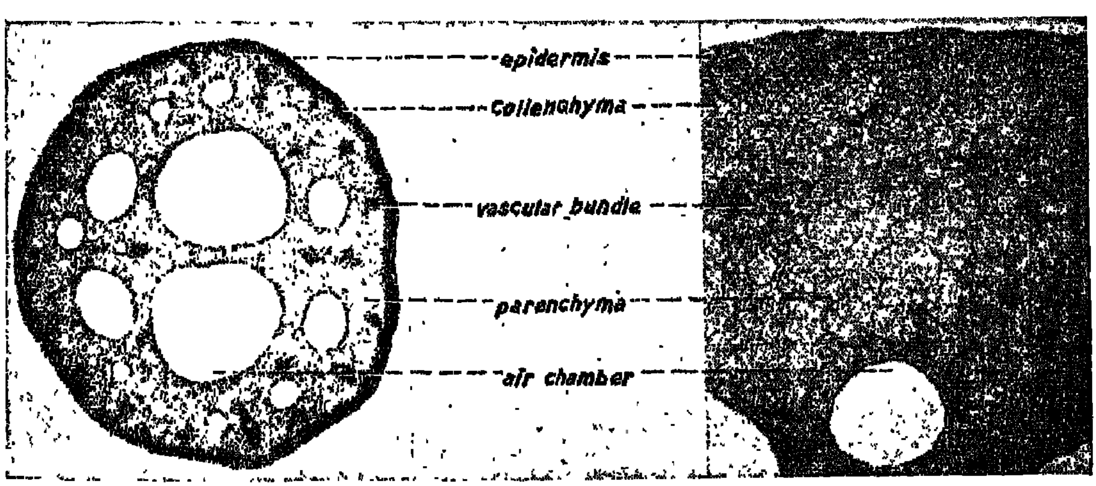


Fig. 54.3. Photomicrographs of the transverse sections of the petiole of *Nymphaea*. The picture on the right is an enlarged view of a part of the picture on the left. Note copious air chambers and scanty xylem elements. Courtesy of the Department of Botany, University of Delhi.

Where the water is not completely covered by the floating plants, the floor of the pond may be cluttered with a dense growth of completely submerged plants such as *Vallisneria*, *Hydrilla* and a herb-like alga called *Chara*. The growth of these plants depends upon the availability of light below the surface of water. If the water is deep or turbid, light does not penetrate far too below, and none of these plants may then occur there. The bottom of a deep pond receives no light or light of very low intensity. Practically no green plants grow there; only saprobiotic organisms—bacteria, fungi, protozoans and some insects live there and carry on the decomposition of dead plants and animals.

Sometimes the entire surface of small ponds is covered by unattached, floating plants like *Lemna*, *Wolffia*, *Pistia*, *Azolla* and *Salvinia*. In addition to these the surface layers of most freshwaters are also inhabited by large numbers of plankton—small, free-floating plants and animals, chiefly algae, protozoans, insects, insect larvae and crustaceans.

Now let us have a look at the animal life of ponds. Since animals feed on plants or on other smaller animals, you would naturally find them closely associated with the plants. Thus, on the plants and in the mud around them you can always observe many small animals, particularly crustaceans, protozoans, flatworms, hydra, pond-snails, leeches and other worms. Insect larvae are also more abundant near the bank than in deep water. Larger animals such as fishes, frogs and tortoises live throughout the pond but they too generally flock near the shores where the food (tender leaves and insect larvae) is plenty.

In flowing waters such as streams, canals and rivers, very few species of flowering plants succeed in gaining a foot-hold; the plankton, and filamentous algae growing attached to the rocks are the primary source of food. Insects as well as other small creatures that may accidentally fall into the stream, and dead bodies of animals, serve as food for many freshwater carnivores.

The Oceanic Habitat

The most obvious thing about the sea is its vastness, in depth as well as in breadth. The average depth of the sea is about 3,800 metres but at places there are deeper trenches. In horizontal spread the oceans cover about 71 per cent of the earth's surface. Besides being vast the sea is a continuous or uninterrupted medium for life. In the oceanic habitat life is plentiful, and the organisms are scattered throughout its extent.

Conditions of life in the ocean. Although the ocean looks like a uniform body of water it actually has three well-defined regions, namely, the continental shelf, the continental slope, and the abyss. The coastal land which continues into the sea for many kilometres is the continental shelf. It forms a sort of submerged platform around the main landmass. The sea water in this region is up to 183m deep. Beyond this the shelf abruptly descends to about 1830m, and forms the continental slope. The abyss is the deep sea. Twice daily, the marginal part of the sea experiences tides and is called the littoral region of the sea shore. The shoreward part of the sea is thus alternately exposed and covered by the tidal water. The organisms living in this region, therefore, experience drastic changes in water level, light and temperature.

Owing to high specific heat of water and to the vastness of the ocean the fluctuations of temperature in the sea are much less than in

freshwaters. However, in the tropical seas the changes in temperature are more marked than in the temperate seas. For instance, the average temperature of surface water in the tropical seas is 26C, at a depth of 200 m it is 13C, at 400 m it is 7.5C, and at 1,000 m and below it is only 4.5 C.

The third important factor in the oceanic habitat is light. It penetrates water in considerable quantity to about 183m. Of course, its penetration is much influenced by turbidity of water. In the open sea, which is clear water, some light can penetrate to a depth of even 920m. The green plants therefore exist only in the upper few hundred metres of the sea; down below only the saprophytic plants and carnivorous animals can thrive.

Sea water contains a high concentration (3.5 per cent) of salts. The body fluids of most marine invertebrates and the cell sap of marine plants also have almost the same salt concentration. These organisms therefore do not suffer dehydration from loss of water.

On the other hand, the body fluids of fishes and most other marine vertebrates, have a relatively low concentration of salts. Therefore these animals constantly lose water. In bony fishes this loss is balanced by excreting very little urine and by drinking large amounts of sea water. Consequently the salt content of the cells increases. The excess salt must be got rid of. This work is done by the gills. The excretion of salts through the gills is not by diffusion, because the salt content of the blood never exceeds that of brine. It is an active process in which respiratory energy is spent.

Sea turtles and marine birds such as penguins and albatrosses get rid of the excess salts through a special structure called the salt gland. In sea turtle the salt glands are situated on the head and open in the corners of the eyes. The salts are excreted as drops through these glands. The notorious crocodile tears are actually the excreted fluid. In the sea birds the salt glands lie just above the eyes and open into the nasal cavity; the excreted salt solution drips from the beak.

Life in the sea. The most striking thing about life in sea is that organisms are found at every depth of the ocean, even in the deepest trenches. The region richest in life is the one near the shore in shallow waters. It is because this region is rich in salts and organic materials that are continuously brought in by the rivers. Secondly, it is the limit to which sufficient light can penetrate and therefore submerged green plants inhabit only this part of the sea. The herbivores which are directly dependent on the green plants also occur in this region in large numbers.

The plant life in the sea can be broadly divided into two groups: (i) the floating forms, and (ii) the fixed or attached forms. The floating plants comprise countless millions of plankton which are the microscopic algae. These serve as food for most marine animals including fish and even such large forms as the whale. Perhaps you find it difficult to believe. Well, they are small in size but occur in such enormous numbers that a drop of brine may contain more than 500 of them! Let us look at it in another way. In India alone nearly two million tons of fish are caught every year. As you know, the whole of it lived at the expense of the plankton. You can now imagine how much more plankton exists in the seas.

The fixed forms of plants comprise a few species of small herbaceous flowering plants, such as *Zostera*, and many kinds of algae which grow attached on rocks and on the muddy floor of the continental shelf. The

different kinds of sea weeds occupy definite depths in the sea in relation to the intensity and quality of light received at each depth.

Now let us have a look at the animal life in the sea. Since the surface layers especially in the shallow waters are rich in plant life, the sub-surface layers teem with floating animals such as the protozoans, crustaceans, larvae of small multicellular animals, the eggs and younglings of various kinds of fishes. Swimming along with them and feeding on the plankton as well as the small animals are the larger fishes, sharks, sea birds, seals, and other animals including the biggest whales. Most commercial fisheries of the world are in fact situated on the continental shelf which swarms with plant and animal life. The floor of the shelf is populated by such animals as crabs, starfishes, brittle stars, worms and molluscs.

In deeper waters the animals are largely carnivorous, but they also feed on the dead remains of animals and plants which sink down from the upper layers. The fishes living near the bottom of the sea are strange animals with black or dark-red bodies, large eyes and light-producing organs. Although they live in deep sea under the enormous weight of the overlying water, they have no special structure to resist the pressure. Probably their natural internal pressure itself is high. That is why when the deep sea fishes are brought to the surface, they just do not stay alive.

On the bottom of the sea relatively few animals live because the food supply is very limited. A notable animal of the ocean bottom is the sea-lily which grows on long stalks attached to the bottom.

The Terrestrial Habitat

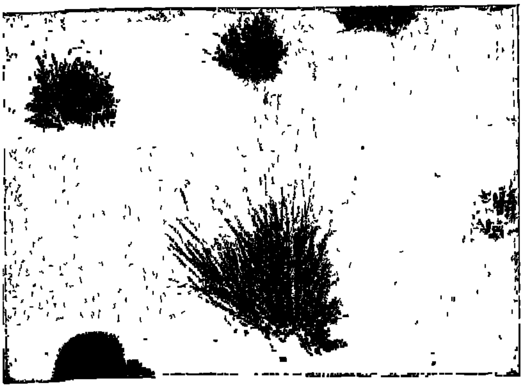
The habitat on land is known as the terrestrial habitat. In this habitat the organisms live in the soil as well as on its surface. Unlike the oceanic habitat, the terrestrial habitat is discontinuous because the various physical barriers such as streams and mountains limit the free spread of the organisms.

Conditions of life in terrestrial habitat. A uniform supply of oxygen as well as light is assured in most regions on land, but the availability of water is uncertain. The organisms living on land are therefore always threatened by the danger of dehydration and desiccation. In fact one of the greatest problems of terrestrial organisms is the economy of water.

In most places on land there is plenty of sunshine; but this causes a wide fluctuation in temperature, both diurnal and seasonal. In deeper layers of the soil, say at 50 cm, such fluctuations are very narrow, and thus the temperature remains moderate all the year round. That is why during extreme summer and winter months many animals burrow underground to escape the extremes of temperature on the surface.

Life in terrestrial habitat. A terrestrial habitat may be mesic, when the availability of water is moderate; or it may be xeric, if water is scantily available. In the mesic habitat, the organisms get enough water to maintain themselves in a properly hydrated condition and therefore no adaptations are required for using the water economically.

Plants that grow in rain forests and those we commonly see in parks, near tanks, temples and other wet places are all mesophytes. In stature they vary from small herbs to large trees. The animals associated with them are those that frequent the mesic habitat.



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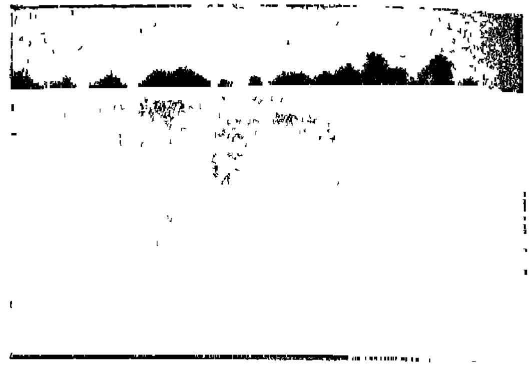

C

Fig. 54.5. Views of desert vegetation near Jodhpur. A. *Lasiurus*. **B.** *Acacia*. **C.** *Saccharum*, *Leptadenia* **and** *Prosopis*. **D.** *Prosopis*. **E.** *Euphorbia*. Courtesy of the Department of Botany, University of Delhi.

D

In xeric habitat only such organisms thrive that have suitable adaptations to save water. We shall now familiarize you with some of the common plants and animals of the xeric habitats (Fig. 54.4). and their adaptations. Deserts are a typical example of xeric habitat. (Fig. 54.5). Other places which receive very little rainfall, and where there is no water for irrigation, are also xeric habitats. There is yet another kind of xeric habitat, namely, the places where water is abundant but is not useful to most organisms either due to the salinity of soil or due to other soil factors.

A familiar xerophyte is the prickly pear (*see* Fig. 10.6, p. 103). Many similar plants, commonly known as the cacti, are also xerophytic. They have succulent tissues in which they store what little water they manage to absorb from the soil. They have a shallow but extensive root system which readily absorbs water before it trickles to the deeper layers of the soil. Their leaves are reduced to mere spines, and thus cut down the loss of water through transpiration.

Fig. 54.4. A xeric habitat near Jaipur. Three typical xerophytes (*Capparis*, *Calligonum* and *Prosopis*) and the proverbial animal of xeric habitats—the camel—are in view. Courtesy of M.A. Rau, Botanical Survey of India, Dehra Dun.

Nerium ('kaner') is another common xerophytic plant. It conserves water in a different way. It has stiff, leathery leaves which show a thick cuticle. The stomata are placed below the level of the leaf surface in deep cavities crowded with hairs (Fig. 54.6). The cavities hold water vapour over the stomata, so that the leaf loses very little water through transpiration. Most of the xerophytic plants have so long been used to dry conditions that they retain their features even when they are grown under mesic conditions.

The animals living in xeric habitats also face difficulty in finding enough water to make up for the loss through breathing and excretion. Being motile, they have the advantage of moving to places where water is available. Therefore, unlike plants they have no structural modifications for storing water. Some of the predators find enough water in the blood of their prey. The herbivorous animals may meet their water requirement by eating succulent plants. When the nights are cool, water condenses on plants and plant debris. In the morning many small animals especially the insects take the condensed vapour.

The most interesting are certain desert animals such as the camels and the kangaroo rats. They can carry on with little water, and also have physiological adaptations to conserve water. Unlike other mammals the camel does not sweat even when the temperature rises to 41C. Its body can function normally even after it has lost water equivalent to 40 per cent of its body weight. However, when water is available, it drinks for nearly 10 minutes to replace the water lost in various ways.

Kangaroo rat is another animal adapted to live in very dry places. It does not drink water, it eats only dry seeds which contain almost no water. It has no sweat glands and it passes concentrated urine. So water loss is negligible. How does it survive then? It uses water that is produced in respiration

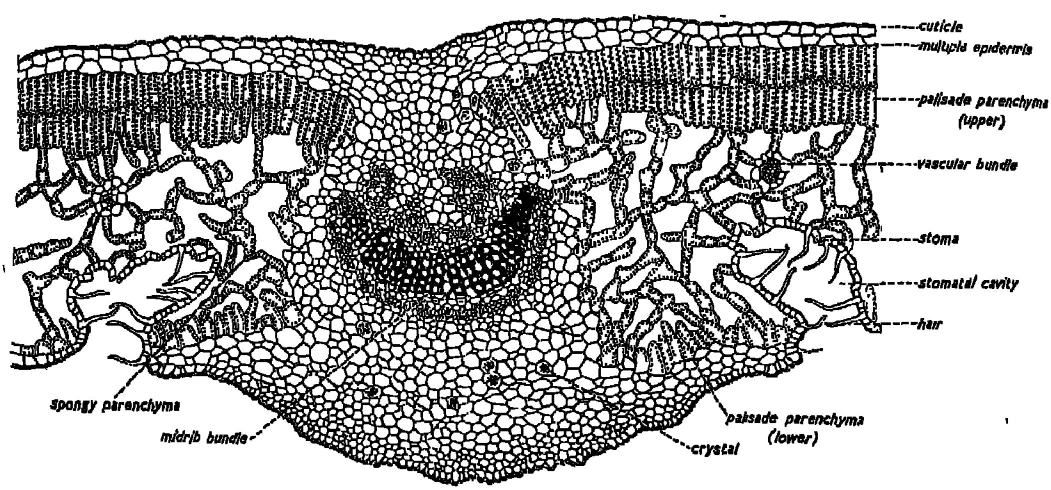

Fig. 54.6. T.S. leaf of *Nerium*. Mark the thick cuticle, double epidermis as well as palisade, and stomata sunk in the cavities which are lined with hairs. Courtesy of the Department of Botany, University of Delhi.

(metabolic water). In other animals metabolic water is just wasted.

Mice, snakes, lizards and other small animals of xeric habitats burrow into the deeper, cooler sand. Birds often build their nests in cool and shady parts of plants.

We have described here only the two chief sub-divisions of the terrestrial habitat—the mesic and the xeric. It should, however, be kept in mind that each of these may have further sub-habitats governed by one or more of the dominating environmental factors. You have already noted in the preceding chapter, that when you climb up a high mountain, you experience distinct changes in the environment and in the types of plants and animals. Similar changes are noted when you go from the equator to the poles.

SUMMARY

There are three major kinds of habitats, namely, freshwater, marine and terrestrial. The organisms inhabiting each of these habitats have a special set of adaptations.

The freshwater habitat has the advantage of a plentiful supply of water, but poses the problems of limited supply of oxygen, and of the unfavourable concentration of salts in the medium. Water makes the organisms buoyant and guards them from extremes of temperature. Each kind of aquatic plant—such as free floaters, attached floaters, reeds, amphibious plants and submerged plants—occupies a definite place in a sheet of freshwater. The animals can scale the entire stretch of water but are generally crowded where food is easily available. Aquatic herbs and algae are the primary food producers of the freshwater habitat.

About 71 per cent of the earth's surface is the marine habitat. The conditions of life in it are in many ways similar to those in the freshwater habitat, but the water has a high salt content and smaller variations in temperature. The life in the ocean is more crowded on the continental shelf where abundant nutrients and enough light are available. Plant plankton form the primary source of food for all marine organisms.

The terrestrial habitat may be xeric or mesic. In xeric habitat the water may be actually scarce or it may be available in a form which most organisms cannot use. In mesic habitats water is available in moderate quantity. Typical xerophytic plants are those occurring in dry areas. *Opuntia*, other cacti, *Acacia* and *Nerium* are some of them. They have special adaptations for saving their water content. Similarly, kangaroo rat and camel have adaptations for life in xeric habitats.

QUESTIONS

1. List the various ways in which water is lost from the body of a vertebrate, and the ways this loss is made good.
2. Both freshwater and marine organisms need to control the transport of water and salts from their bodies. How does the mechanisms of control differ in the two?
3. Contrast the structural features of a mesophyte and of a hydrophyte; of a mesophyte and of a xerophyte.
4. Compare the physical factors of environment of the sea with those of the freshwater.
5. Name five of the most common adaptations of the freshwater plants.
6. List the important environmental factors that influence the terrestrial organisms.
7. What are the three main zones of the ocean? Describe their characteristics.
8. Name five hydrophytes other than those mentioned in this chapter.

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SECTION 7

General

CHAPTER 55

Interdependence of Plants and Animals

PLANTS and animals are influenced not only by the environmental factors such as light, water, temperature and wind, but also by one another. There is a partnership among living things. For instance, bees collect nectar from plants and at the same time bring about pollination. Birds gather food from plants, disperse their seeds and also kill many harmful insects. In this chapter we shall learn some

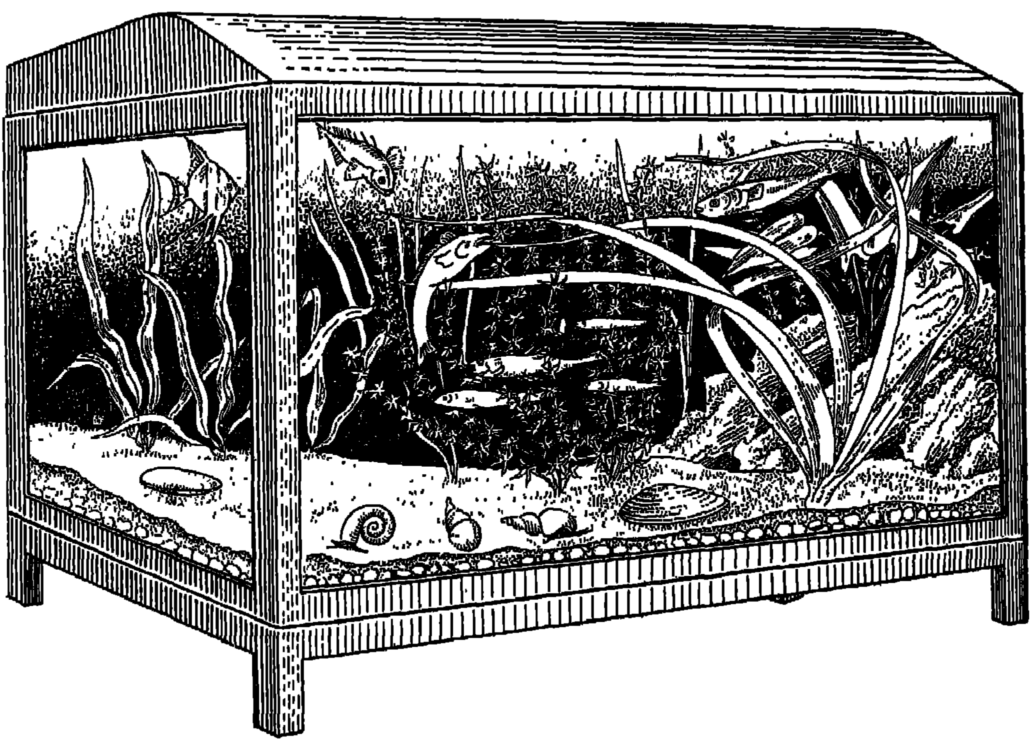

Fig. 55.1. A home aquarium is an example of a balanced biotic system. Sunlight is the primary source of the energy utilized by green plants to synthesize food with a simultaneous liberation of oxygen. Animals feed on plants and in turn supply the plants with carbon dioxide and nitrogenous wastes. Courtesy of the Department of Botany, University of Delhi.

important and interesting facts about the interdependence of plants and animals.

At the outset we may consider the working of a home aquarium (Fig. 55.1). The green plants in such an aquarium provide food to the fishes directly, or harbour other organisms upon which the fishes feed. The plants also liberate oxygen during photosynthesis and utilize the carbon dioxide given off by fishes during respiration. The wastes of fishes serve as a fertilizer for the plants and this incidentally helps to keep the aquarium free of the animal excretions.

Oxygen for Respiration

Respiration, which is essential for the life of all plants and animals, goes on day and night. This process involves a continuous consumption of oxygen and release of carbon dioxide. The amount of carbon dioxide in the atmosphere is also increased (and that of oxygen decreased) by the combustion of wood, coal and oil. This would naturally mean a gradual depletion of oxygen in the atmosphere.

While green plants respire all the time, in the presence of sunlight they also carry on photosynthesis. Since this process is far in excess of respiration, there is a net release of oxygen during the day. Thus, green plants are able to return to the atmosphere a gas which is indispensable for life on earth.

Food and Food Chains

Apart from oxygen, plants are also the source of food for all the animals on earth. The capacity to synthesize organic food from inorganic substances is a monopoly of green plants. Animals and plants devoid of chlorophyll such as moulds and mushrooms require ready-made food.

One might argue that a lion never eats plants and could therefore survive even if all the plants were to disappear from the earth. Well, a lion eats the deer which in turn lives on plants. To cite another example, the vultures eat snakes, the snakes eat frogs, the frogs live on insects, and the insects feed on plants. All such organisms which are linked to each other by what they eat form a **food chain** (Fig. 40.1). The starting point in any food chain is always a green plant, because green plants alone have the capacity to capture energy from sunlight. The vast animal life in the seas is also supported by the photosynthetic activity of the minute algae collectively known as phytoplankton. Usually there are many food chains in a plant-animal community. They overlap and are connected at different points forming what is called a food web. All food chains and food webs whether in the sea, forest or desert, follow the same general plan: plants—herbivores—small carnivores—large carnivores.

There is a balance in Nature with regard to these food chains. Any disturbance caused by climatic conditions or by man results in the upsetting of the whole system and it takes some time to establish the balance once again. For instance, if birds are killed, the insect pests may increase in number so rapidly that they will ruin the crops. Thus, the relationships of the plants, animals and their environments are very complex. A bird is not simply an animal which consumes the food that we may need, but it is one of the many links in a food chain.

Some animals depend upon specific plant food. The caterpillar of silkworm, for example, feeds only on the mulberry leaves. Each larva exudes fluid silk which hardens into a thread on contact with air. This thread is wound round the caterpillar to form the cocoon. The moth is killed at the pupal stage and the thread is removed. Each cocoon yields about 300 metres of fibre.

Another example of dependence on specific plant food is that of the lac insect (*Lac-*

cifer lacca) which lives on the sap of certain host plants. Lac is secreted by the adult females as well as the developing larvae (Fig. 55.2). This product is of great commercial importance and it may interest you to know that nearly 75 per cent of the world supply of lac is from India.

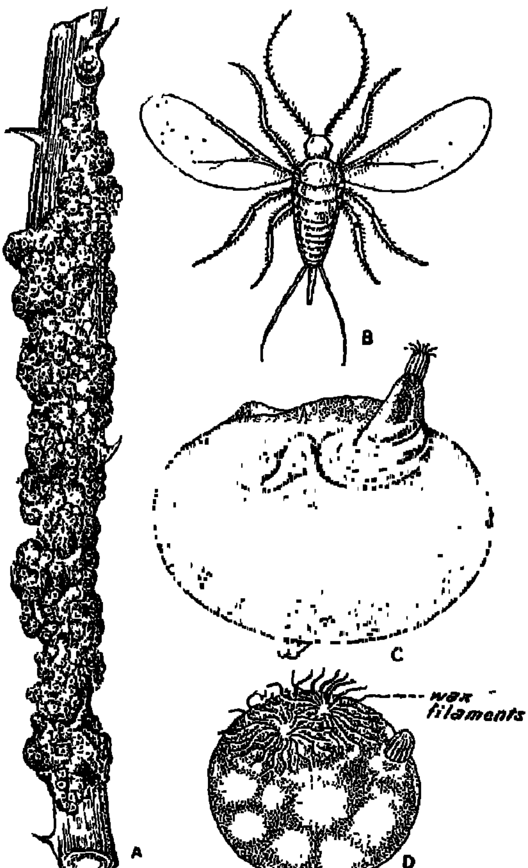

Fig. 55.2. A. Twig of *Zizyphus* showing a heavy deposition of lac. B. The male lac insect. C. The female lac insect. Note that the adult female lacks wings. D. The lac chamber of a female insect. The larvae pour out a resinous material which hardens around their body. The hardened resin is known as lac chamber or cell. It bears wax filaments which help in breathing. Finally an adult male or a female insect matures in each cell. A, courtesy of the Department of Botany, University of Delhi. B, C and D, courtesy of the Indian Shellac Bureau, Ranchi.

Natural Scavengers

When plants and animals die, their remains are decomposed by saprophytic bacteria and fungi. The spores of these organisms are found everywhere—on land, in sea and in air. Wherever there is a bit of organic matter, these spores reach it and begin to germinate. The complex organic substances in the dead bodies of plants and animals are reduced to water, carbon dioxide, ammonia and simple mineral compounds. By this method the essential elements are returned to soil and air, and are made available for future generations.

Green plants are responsible for changing the inorganic matter into organic form and the non-green plants bring it back to the inorganic state. This return to the starting point completes a 'cycle'. Several cycles such as those of water, nitrogen, carbon, phosphorus, oxygen and sulphur are known in Nature. All of these operate continuously. In most of the cycles, the soil, plants and animals play an important role.

Cross-pollination

Since most plants are attached to the soil, they have to depend upon external agencies to bring about cross-pollination. It is believed that originally all plants were pollinated by wind. Some insects probably developed the habit of feeding upon pollen. The plants gradually developed features favouring insect pollination: Showiness due to colour, size or aggregation of flowers; fragrance due to volatile oils; nectar; sticky pollen and other structural adaptations.

A variety of animals take part in the act of pollination: Bees, wasps, butterflies, moths, beetles, houseflies, birds and bats. The time of the opening of flowers, their size, colour and shape are all adapted to

the specific type of pollinating agent. The nectar and pollen serve as food for pollinating insects. The honey-bee gathers large amounts of pollen in addition to the nectar. This pollen is mixed with honey and is fed to the young bees.

Many species of plants, including such important crops as fruits, legumes, cucurbits, and crucifers, depend upon insects for pollination. Fruit growers and greenhouse men commonly keep beehives to ensure pollination for proper seed and fruit production.

While most cross-pollinated plants have the usual attractive features mentioned above, there are instances of an extreme specialization and dependence of one species of plant upon a particular type of insect. *Yucca* is one such plant. It bears clusters of white, bell-shaped flowers (Fig. 55.3) which open during the night and emit fragrance. The only insect which can pollinate these flowers is a tiny, snow-white yucca moth called *Pronuba yuccasella*. The mouth parts of the female moth are especially suited for the collection of pollen. She emerges soon after dusk, collects pollen from a flower, rolls it into a ball and flies to another flower. There it inserts the ovipositor into the ovary and deposits eggs between the ovules. Subsequently the moth moves to the tip of the pistil and carefully thrusts the ball of sticky pollen grains into the funnel-shaped stigma. The ovules of *Yucca* and larvae of the moth grow together and the caterpillars feed upon the developing seeds. While many seeds are consumed, some are still left in each fruit for the propagation of the plant.

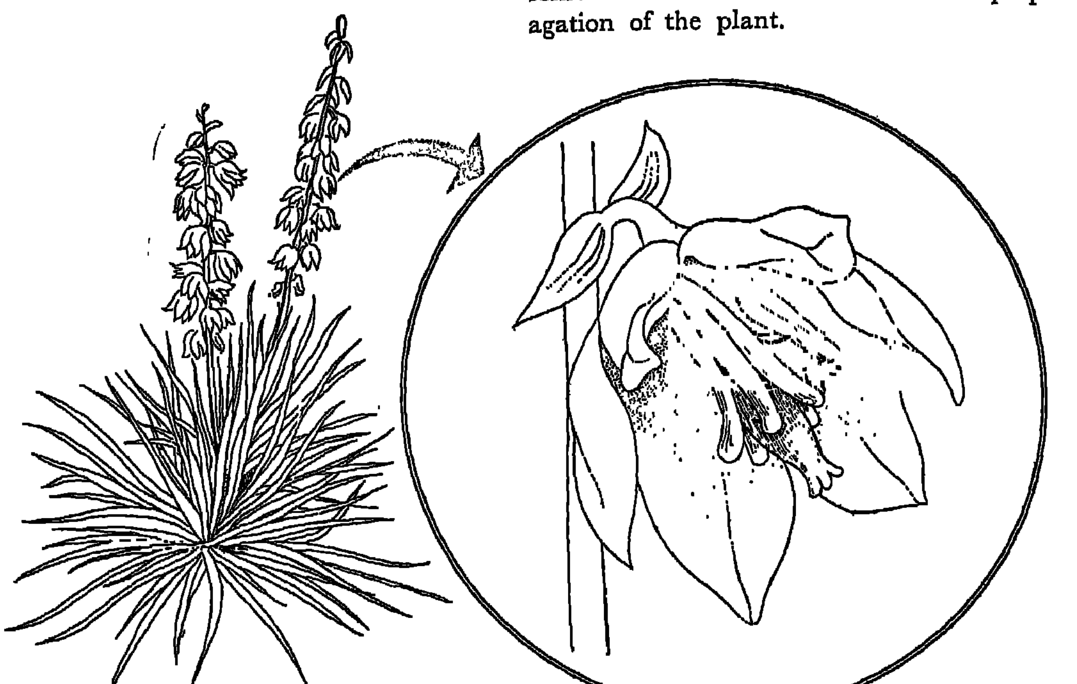

Fig. 55.3. The *Yucca* plant and the yucca moth provide a striking example of life-for-mutual benefit. The enlargement shows a moth collecting pollen from the anthers. After C.W. Young, G.L. Stebbins and F.C. Brooks, *Introduction to Biological Science,* Harper & Brothers, Publishers, New York, 1965.

Finally, the caterpillars bore holes in the wall of the green fruits. As each of them emerges, it spins a silver thread by means of which it lowers itself. Then it digs into the ground and undergoes further development there. The moth emerges from the cocoon only in spring when the yuccas are about to flower, and the acts of laying eggs and pollination are repeated. Thus, the life cycles of these two organisms are very well timed and have resulted in an unusual partnership called **mutualism**. The moth is indispensable to *Yucca* and the latter is indispensable to the moth.

Another striking example of complete dependence is that of the edible fig (*Ficus carica*; Fig. 55.4) and the fig-wasp (*Blastophaga grassorum*). The fig-wasp completes its life cycle only inside the figs on male trees. As the wasps emerge from these figs their bodies become smeared with pollen grains, and pollination is brought about when they enter the figs on female plants. If this process fails, the figs drop off and fruits do not develop. Early attempts to grow edible figs in California (USA) were unsuccessful until the pollinating wasp was also introduced.

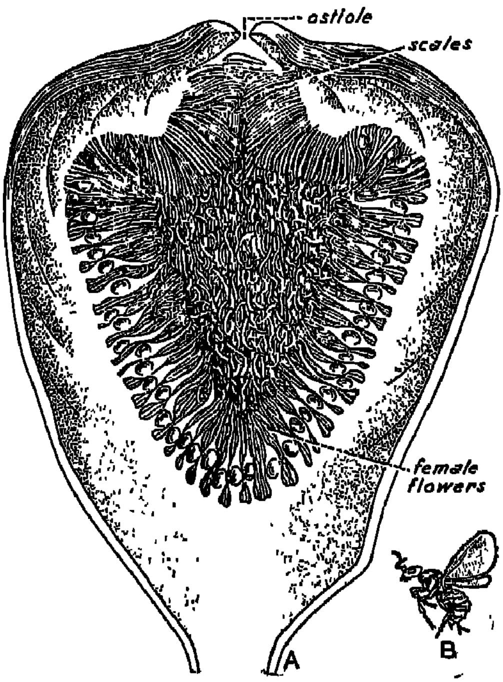

Fig. 55.4 A. Longitudinal section of a young fig showing the female flowers ready for pollination. The wasp (B) enters through the narrow opening (ostiole) at the top, and pollinates the stigmas with the pollen brought from the functionally male figs. Courtesy of the Department of Botany, University of Delhi.

Dispersal of Seeds by Animals

Several plants are dependent upon animals for the dispersal of their seeds. Seeds and fruits have no legs or wheels but they have a variety of devices for using the services of those who have them. Many fruits attract birds and humans who discard the seeds after eating the fleshy parts. Cattle also eat the fruits of several plants and pass out many uninjured seeds with their droppings.

The fruits of many weeds like *Achyranthes*, *Pupalia*, *Tribulus* and *Xanthium* have hooks or prickles with which they stick to the animals and drop off here and there. The production of sticky seeds is yet another device for dispersal. Many nut-bearing trees seem to be benefited by the storing instincts of squirrels. They bury the nuts for future use but often forget about them and those which are not consumed may grow into new plants.

Man himself introduces useful plants from one region of the world to another. With the modern modes of transport e.g. trains, ships and aeroplanes, the seeds of weeds are also dispersed, unintentionally, to long distances.

Effects of Grazing

Grazing reduces the photosynthetic organs of plants and results in decreased

food production. When young plants are grazed too heavily, the roots are starved, the plant is weakened and eventually killed. The grazing animals also cause mechanical injury to the young seedlings by trampling them. Another effect of heavy and continued grazing is that the upper layers of soil are loosened and are easily removed by wind and water. The lower layers, on the other hand, are made more compact which makes it difficult for the roots to penetrate them. This also reduces soil aeration and thus interferes with the respiration of roots. Further, by elective grazing, animals reduce the number of palatable plants and these may eventually be wiped out from a particular locality. The inedible ones, on the contrary, get a chance to multiply and dominate the vegetation. The only way grazing animals help vegetation is that they add their excreta to the soil.

Although rodents are much smaller in size than cattle and sheep, their number is often so great that they cause considerable damage to the vegetation by eating the leaves and underground parts. Tremendous quantities of seeds are also consumed by rats and squirrels and this reduces the capacity of plants to multiply. In addition, the rodents injure and expose the underground parts of plants by their burrowing activities.

Plants have adaptations to defend themselves from animals. These may be mechanical such as thorns, spines and prickles; or chemical such as irritating acids and poisons which are responsible for the death of cattle.

Role of Earthworms

These little animals perform a very important biological role in moist soils. They come out at night and consume the remains of plants on the surface of soil. While coming up, they swallow soil and mix it with some of the partially digested organic matter. To this soil are also added the excretory wastes and other secretions of the worms. This well-ground soil, rich in organic matter, is finally left on the surface in the form of castings. The amount of soil brought up from below has been estimated to be as high as 18 tons per acre per year. Fertility is greatly reduced in soils from which earthworms are excluded.

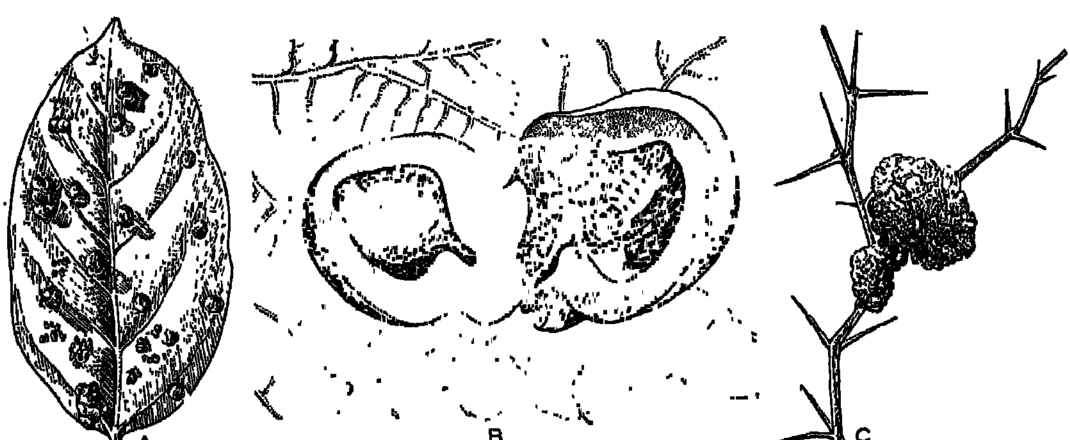

Fig. 55.5. Some examples of plant galls caused by insects. A. The leaf of *Ficus glomerata* with many rounded galls. B. A gall split open to show the insect in the cavity. C. A large gall on the twig of *Acacia leucophloea*. Courtesy of the Department of Botany, University of Delhi.

The burrowing habit of the worms improves soil aeration and drainage, and also makes the downward growth of roots easier.

Shelter for Animals

Many insects such as flies, aphids, wasps, moths and beetles induce the formation of galls on plants. The female deposits eggs in the tender tissues of the growing leaf or stem. The plant tissues grow rapidly all around the larva resulting in the formation of a gall (Fig. 55.5). The gall is helpful to the insect in two ways. Its thick outer layers protect the developing insect from its enemies. Secondly, the inner tissues of the gall are rich in nutritive materials and are a ready source of food. The insect continues to feed on the inner tissue of the gall until only a thin outer membrane remains. This is finally pierced when the insect is ready to fly. Some kinds of galls open by themselves.

One of the most fascinating insects which rolls up the leaves is the cricket. It secretes silken threads from a pair of glands in its mouth and uses them to roll the leaves. During the day time it protects itself from birds and other enemies by hiding in such 'leaf tents'.

Apart from such special 'houses' made by insects, the type of vegetation of an area determines the number and kinds of animals that can live there. A thick forest, for instance, can give shelter to animals like lion and elephant which cannot live in the open.

Fig. 55.6. The Venus flytrap—a curious insect-eating plant. The apical halves of the leaves are sensitive to the touch of insects or small animals and quickly close to enjoy a non-vegetarian meal. After Anton Kerner von Marilaun, *The Natural History of Plants*, Vol. 1, Blackie & Son, Limited, London, 1894.

Carnivorous Plants

While the dependence of all animals on plants for their food is quite evident, there are also certain plants which depend (at least partially) on animal diet. These are called the carnivorous plants. In these plants the leaves are modified in various ways. Some, like the pitcher plants (Fig. 13.4, p. 132) have a passive trapping mechanism; others like the sundew (Fig. 13.4) and Venus-flytrap (Fig. 55.6) show active movements for capturing the prey. The aquatic bladderwort (Fig. 13.4) catches water fleas, young mosquitoes and even small tadpoles. The carnivorous plants secrete enzymes which slowly digest the softer parts of the captured animal (insect, snail or spider). The

products of digestion are absorbed by the tissues of the leaf.

Animal and Plant Partners

Several lower animals such as species of *Paramecium*, *Hydra*, freshwater sponges, mussels and snails often contain algal cells. In many cases the alga is a species of *Chlorella* called *Zoochlorella*. The animal gets carbohydrates and oxygen resulting from the photosynthetic activity of the green alga. The dead algal cells are also digested. The alga in turn, gets nitrogen and a part of its carbon dioxide requirement from the animal.

The alga passes from one generation to the next through the eggs of the animal. These animals can live without the alga but with it they are able to carry on even in the absence of any solid food in water.

Intestinal bacteria. We take in lots of bacteria with food. Bacteria which are not killed by the acidity in the stomach multiply rapidly and their number runs into billions. Some of them bring about putrefaction resulting in foul gases. They also deprive us of a part of our food. In the process of manufacturing vitamins for themselves bacteria may also produce some vitamins which we can use.

Cattle, sheep and goats depend on microbes not merely for their vitamins but also for a good part of their food. Cows eat mostly grass and hay, which consists largely of cellulose. Cows cannot digest this material without the help of microbes. When a cow chews her cud, she mixes the hay with many bacteria and protozoa which live in her stomach. After these microbes have digested the cellulose the material passes into the stomach. The microbes thus prepare the food for the cow and can be considered 'welcome guests'.

Harmful Insects

While most insects are useful to the plants, some are quite harmful. Swarms of locust, for instance, ruin the standing crops. Other examples of harmful insects are moths, bugs, beetles, ants, house-flies, termites and cockroaches which damage forest trees, ornamental plants, and stored food. The insects also spread some important viral diseases of plants.

Diseases

While most bacteria and fungi derive their food from dead organic matter many are parasitic and cause diseases in both plants and animals. As examples of fungal diseases of man may be mentioned the ringworm and athlete's foot. Several bacteria cause infectious diseases of man and domestic animals like chicken, sheep, goats and horses. Tuberculosis, cholera, typhoid, leprosy, tetanus, plague, pneumonia, diphtheria and blood poisoning are some of the deadly diseases caused in man.

One possible benefit of parasites is that they keep the number of animals in check. With the enormous increase in the population of any particular animal, a disease may spread more rapidly and kill a large number of individuals of that species.

Activities of Man

With the advance of civilization man has become more dependent upon plants and animals. His activities, on the contrary, do more harm than good to the rest of the organisms on earth. Man has killed various species of animals for food, clothing, personal protection or just for sport. Some species have become extinct while others have been greatly reduced in number.

Agriculture. Our agricultural practices, building activity, communication lines, etc., involve the removal of natural vegetation, and with it the driving away of the wild

animals from their natural abodes. Moreover, by raising large numbers of plants and animals of the same kind, excellent conditions are provided for certain insects and other disease-producing organisms which multiply at a rapid rate and cause serious problems. By harvesting the crop we remove much of the organic matter which would normally have gone back to the land through decay. The fertility of soil is, therefore, reduced and fertilizers have to be added to restore it. When man removes the trees in a forest by cutting or by burning them, he also exposes the soil to the agents of erosion.

Disposal of sewage. The sewage from big cities is put into the rivers. This has an adverse effect on the aquatic plants and animals for several miles. The fishes suffer great losses due to the lack of oxygen caused by pollution.

Introduction of foreign plants and animals. Thoughtless introduction of foreign animals and plants often has very drastic effects. The prickly-pear cactus (*Opuntic*) was introduced in India many years ago and became a very troublesome weed. Later, the cochineal insect (*Dactylopsis coccus*)—which greedily feeds on this cactus—was introduced and the situation brought under control. To cite another example, a few pairs of rabbits were brought to Australia by the early colonists. In the absence of carnivores like hawks and foxes, the rabbits multiplied tremendously and became a source of great trouble for the farmers. In their original homes most animals and plants have natural enemies which keep their population in check, but in the changed environment they multiply very rapidly.

Plant and animal improvement. Any account of man's influence on other organisms will not be complete without stating that he has also improved the quality of numerous animals and plants by selection, hybridization and mutation. The improvement of plants and animals started as soon as man began to cultivate plants and domesticate animals.

Fig. 55.7. Best bull of the Malvi breed—a 'creation' of the animal breeder. Courtesy of the Press Information Bureau, New Delhi.

Selection of the best seed for the following year's crop and of the fittest animal for further breeding are very old practices. However, selection has its own limitations and one cannot usually produce an offspring which is superior to the 'good' parents. By hybridization it is possible to combine the good qualities of the parents. This is a very powerful tool in the hands of man, especially after his understanding of the laws of heredity. Crosses have been made not only between different varieties

but also between different species. The mule is a very good example of this type of breeding.

The objectives of hybridization vary considerably. For example, dogs may be bred for their intelligence, appearance, strength, or hunting ability. The considerations in cattle breeding are greater yield of milk, flesh or wool; quality of products; hardiness; or body form and early maturity. Beef cattle, race horses, sheep, cows and bulls (Fig. 55.7) are some of the numerous examples where significant improvement has been made.

The important considerations in plant breeding are: resistance to drought, frost, disease and insect pests; greater yield, vigour and size; superior quality of products; early ripening; colour of flowers and fruits; and production of seedless fruits. Hybrid corn is an outstanding example of such attempts in the USA. In India considerable work has been done for the improvement of wheat (Fig. 55.8), cotton and sugarcane.

Fig. 55.8. An improved variety of wheat—the outcome of laborious efforts of the plant breeder. Several varieties with high yield, better grain quality and resistance to disease-producing fungi have been produced by planned hybridization. Courtesy of the Press Information Bureau, New Delhi.

In fact, Indian canes rank among the best canes of the world.

In recent years natural and induced mutations have been used for the production of new and unusual varieties of ornamental plants and fruit trees.

Of late, man has also sought to preserve animals and plants on way to extinction by prohibiting their destruction and by providing favourable places for their breeding and safe living.

SUMMARY

The two major groups of organisms, plants and animals, are very closely associated with each other and tend to be in a state of equil-ibrium. While animals bring about cross-pollination and dispersal of seeds and fruits, their very existence depends upon the oxygen and food provided by green plants. Furthermore, the earth is made a fit place to live in by the activities of saprophytic bacteria and fungi which decompose the dead remains of plants and animals. The important chemical elements are thus kept in constant circulation.

Carnivorous plants are very peculiar since they have special adaptations to utilize food of animal origin. Bacteria and fungi cause several serious diseases of man and animals.

While man improves the quality of plants and animals by selection and hybridization, his activities in general are harmful to other organisms.

QUESTIONS

1. What are food chains? How is it that the starting point in any food chain is always a green plant?
2. A friend of yours took the following during one day:
   a. Cod liver oil
   b. Egg
   c. Mutton
   d. Butter
   e. Bread.

   Trace the food chain in each case.
3. Define the term 'cycle'. With what kinds of cycles are plants associated?
4. How does the introduction of foreign plants and animals upset the equilibrium in Nature?

FURTHER READING

YOUNG, C.W., STEBBINS, G.L. and BROOKS, F.G. 1956. *Introduction to Biological Science*. Harper and Brothers, Publishers, New York.

PARKER, B.M. and BUCHSBAUM, R. 1949. *Balance in Nature*: The Basic Science Education Series. Row, Peterson and Company, Illinois.

CHAPTER 56

The Span of Life

IN Chapter three you learned what characterizes life. The period from birth to death—the **life span**—varies from organism to organism. Figure 56.1 gives you an idea of the highest age records of some common plants and animals. All living things age and show symptoms of it. With the passage of time the chances of survival decrease and the susceptibility to death increases.

Under favourable conditions one bacterium divides into two bacteria every 15 to 20 minutes and looses its identity. There seems to be no natural death because there is no corpse. At this rate the products of a single bacterial cell would cover the whole earth up to a thickness of one foot within 36 hours. However, when cultured on a suitable nutrient medium the growth rate falls with time. This is because the bacteria release certain toxic products into the medium and cause their own death. If these toxic substances are not allowed to accumulate, the high rate of growth can be maintained and death can be avoided. Under these circumstances the age of an individual bacterial cell may be considered to be equivalent to the generation time (time lapse between the formation of a new individual and its division).

Among the lower plants and animals the life span varies considerably. Some mosses and liverworts keep growing at the tips for years as the older parts wear off. Insects that come up during the rainy season have a brief existence of only a few hours. They seem to live only to reproduce. The case of the seventeen-year locust is curious. As the name suggests it lives for 17 years, but most of this period is spent underground in development. After their emergence, the insects live only for a few months or a year.

The seed plants are grouped into three categories depending on their length of life. Annuals such as wheat and rice germinate, grow, flower, set grain and perish in one season. Some species complete their life cycle in just three weeks. *Anagallis*, a tiny plant with pretty bluish flowers, is one such example.

When cultivated in colder areas, plants like wheat, carrot and cabbage, behave like biennials because they have two growing seasons. During the first season they produce only leaves and branches and in the next, they form flowers, fruits and seeds. The perennials live for many seasons and may flower every year.

In the annuals and biennials the developing seeds and fruits exhaust the food reserves of the plant and hasten death. Exhaustion due to reproduction may also cause death

in some insects, scorpions and fishes. Prevention of fruiting by removal of flowers prolongs the life span but does not prevent death. Perennial plants are unaffected by flowering although their growth rate is temporarily reduced. The individual organs like leaves, flowers and fruits age like animals and are shed periodically. Leaves become functionally less efficient as they age. The green colour disappears and the nutrients pass

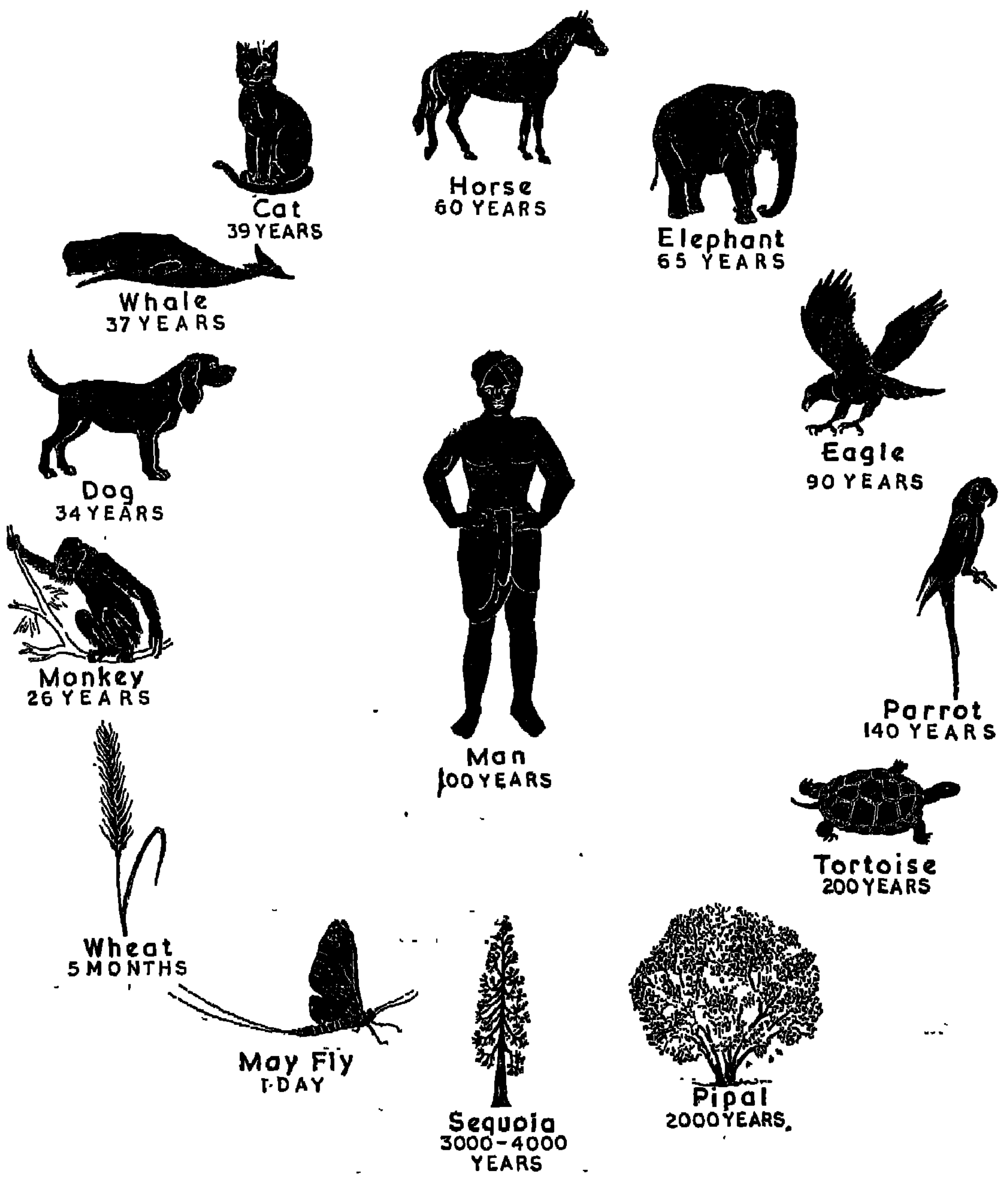

Fig. 56.1. Duration of life of some common plants and animals. Modified from *Courier*, courtesy of UNESCO Office, New Delhi.

back to the plant. A tree is thus benefited by ridding itself of ineffective organs and replacing them by more efficient ones.

The figures for the longevity (length of life) of some trees are remarkably high. A *Macrozamia* tree growing in Queensland, Australia, is claimed to be 12,000 years old; but it is hardly seven metres in height. The dragon trees (*Dracaena draco*) of the Canary Islands (west of Morocco in the Atlantic ocean) have been estimated by some persons to be 8,000—10,000 years old.

A handsome tree which attracts thousands of tourists every year is the 'Big Tree of Tule' —a 2,000 years old specimen of cypress (*Taxodium mucronatum*) in Mexico. It is 29 metres high and has a diameter of 17 metres. The sequoias live from 1,000—4,000 years! Some of these specimens were contemporaneous with the ancient Egyptian and Indus Valley civilizations !

Compared to the astounding ages to which some of the trees can live, animals have much shorter lives. Men, who have passed the age of 100, are very rare. On an average only two or three centenarians can be found in a population of 100,000. Claims of age greater than 110 have been found unreliable. The centenarians belong to no particular group. They include gluttons and small eaters, meat eaters and vegetarians, smokers and non-smokers. It is difficult to find any one reason which could have extended their lives. Curiously, women live longer than men. Fewer female children die at birth than their brothers. Women also have greater powers of physical and mental endurance.

The animal which outlives man is the slow and steady tortoise. The tortoises, which live in the Galapagos and Seychelles islands, have an average life span of 100-150 years; some reach even 200. Elephants live up to 60 years, although some individuals live beyond 70. It is difficult to estimate the age of wild birds. In a flock of parrots in the woods, one may not see the really aged individuals. Caged parrots are known to have lived beyond 140 years. The swan, eagle, vultures and owl live as long as man.

The animals in a zoo which enjoy a permanent home, protection from enemies and abundant food live longer than their wild cousins. However, they also show signs of ageing. Parrots lose their memory and even become bald! With advancing age, the vigour decreases, the muscles become weaker, the bones become brittle, the teeth wear out, the eyesight fails, and the replacement of skin, hair, cells of the cornea and blood corpuscles slows down. The wound healing capacity decreases with increasing age. Changes due to ageing become highly disadvantageous to the older members of a group of wild animals which compete with each other for all the necessities of life.

Greying of hair, wrinkling of the skin, bending of the back, and loss of memory are the common symptoms of old age in man. Older people are more susceptible to diseases of the heart, kidneys, eyes, nervous system, and to cancer and paralysis.

The average human life span varies from country to country. The average life-expectancy is calculated by collecting information about the age at death of a group of people. Census reports and insurance companies are good sources of this information.

Four hundred years ago, the average length of man's life in Europe was 19 years. Of course some reached great ages even then. But more than 50 per cent of the babies died at birth. Now the average life span is nearly 65 years and only 30 to 40 out of a thousand children die before they complete one year. Such a remarkable change was possible due to mass scale immu-

nization to diseases, better homes and food, and improvement in general hygienic conditions.

Even 80 years ago a new born baby in India would have lived on an average for only 23-24 years. In the period from 1911-21 India suffered from serious attacks of influenza, floods, drought and famine. Life expectancy went down to about 20 years. Improvements in public health, medical care and food supply increased the average life span to 26.7 years during 1921-30. Today an Indian can hope to live 41.2 years. However, we still lag behind some other Asian countries. The expectancy of life is 67.8 years in Japan (1960), 59.9 years in Ceylon (1954) and 51.0 years in the Philippines. Further improvements in our expectation of life are possible only if the rate of child mortality (145 per 1,000) is reduced to the minimum and the epidemics are conquered. A look at figure 56.2 shows that there has been a slight fall in death rate, and a small rise in birth rate.

There is no single cause of death. All the organs of the body do not age at the same rate. When the dead body of an aged person is cut open and examined, one finds numerous conditions which could have caused death besides the one which triggered it. In a way death is accidental.

Another important question which arises in one's mind is whether the cells age because the organism which they compose ages or is the organism affected by the ageing of the cells. An elephant and a rat look different but are built more or less on the same plan. They have organs which perform similar functions and secrete the same substances. Yet the cells of the liver of a rat have a shorter life than those of an elephant. It seems that it is the genetic constitution of the organism which determines how long cells should live.

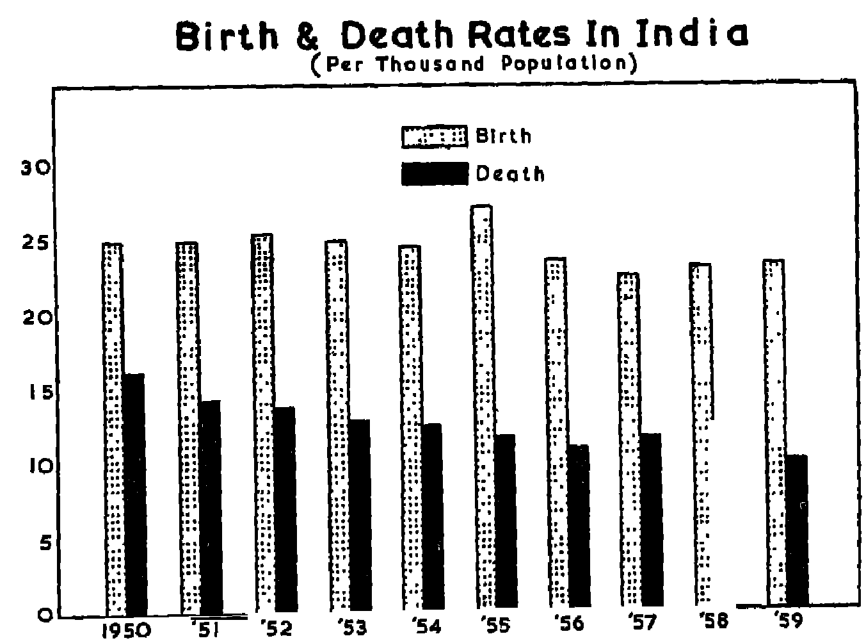

Fig. 56.2. Birth and death rates in India during the period 1950—1959. Courtesy of the World Health Organization, New Delhi.

In general, the smaller and more quickly reproducing a creature is, the shorter is its length of life. If the time taken to attain the maximum size and to produce the offspring is short, the life span is also brief. If immature rats are given a low-calorie diet their length of life becomes nearly doubled.

Tissues which regenerate themselves by cell division continue to live. The shoot and root tips of perennial trees have actively dividing tissues called meristems which are capable of eternal growth. A piece of the heart of a chick or a bit of the root of carrot can be maintained in an active state of growth for over 25 years in tissue culture. Nerve cells follow a man from cradle to grave without division. Yet they retain their activity.

Numerous changes can be noted in the cells as they age in an organ. It is not known whether these are the causes or the effects of ageing. Breakdown of proteins, decrease in the number of mitochondria, exhaustion of enzymes, deposition of certain pigments, calcium, iron, cholesterol, and loss of permeability of cell membranes are some such changes. In muscles, heart, kidneys and lungs, nearly 40 per cent of the cells may be dead when a man reaches the age of 75. This cell loss decreases body strength and activity.

Scientists have failed to find any single chemical substance which could control ageing. However, some exciting discoveries have been made in this quest. Several years ago, Wiggelsworth of Cambridge University, England, discovered a hormone in insects which prevents them from maturing. This is called the **juvenile hormone.** If this hormone is injected into a silk-worm caterpillar, its metamorphosis into an adult is inhibited. If the injections are stopped, normal development occurs.

Exposure to some radiations accelerates the normal processes of ageing. When the first atomic bomb exploded in Hiroshima, an island of Japan, in 1945, people aged overnight. A group of 2-month-old rats exposed to a radiation dose of 400r shows signs of ageing and approaching death like 12-month-old rats. Mortality increases with an increase in dosage. With the present danger from atomic explosion, its effect on ageing has become especially important.

Even if we understand the causes of death, it may not be possible to postpone it indefinitely. What one might attempt usefully is to find out if disease and death may be prevented in people before they reach a ripe age. This will enable them to live a more vigorous and useful life and not be handicapped prematurely. After all, if we understand why we die, death may cease to be that frightening or unpleasant.

The most important way man has been able to lengthen his life has been by the conquest of disease, hunger and poverty. In the next chapter you will read how man has succeeded, after thousands of failures to understand, control and prevent the chief human diseases.

SUMMARY

The period from birth to death is called the life span. All multicelled organisms die sooner or later. Some show definite signs of ageing. Unicellular organisms like bacteria, however, have no natural death because the original cell divides into two, and loses its identity. No corpse is left behind.

Some insects exist only for a few hours. In contrast, some conifers live for over thousand years. Annual plants live for one season; the biennials for two and the perennials for many. Men having passed the age of 110 years are extremely rare. The only animal which outlives man is the tortoise.

What determines differences in longevity is not known. There is some evidence that heredity plays a role in it. In the growing tips of perennial trees, cells undergo continuous divisions. These tissues are nearly immortal. It is now possible to remove pieces of tissue from the heart of a chick or from the root of a mature carrot and grow them for many years in tissue culture.

With advancing age, many changes occur in the organs, tissues and cells. The number of cells in an organ decreases and the ability to heal up wounds is gradually lost. There is no single cause of death; it seems to be invariably accidental. Growth and development are under the control of hormones. The metamorphosis of insects is retarded by a hormone called the 'juvenile hormone'. Radiation effects resemble symptoms of ageing. Improvement in diet, general health, sanitation, education and the conquest of diseases have been chiefly responsible for the gradual increase in man's life expectancy at birth.

QUESTIONS

1. Suppose that a bacterium duplicates once in every 10 hours. Why does it not fill up the whole of the earth in a calculated period of time?
2. What is peculiar to the 17-year old locust?
3. How are the seed plants classified on the basis of their length of life?
4. How does a tree benefit by periodically shedding its leaves?
5. Name the oldest living plant on earth.
6. Why is it uncommon to see very aged individuals in a flock of birds?
7. List as many differences as you can, between a boy of 15 years and a man past 70 years in age.
8. An average Indian lives 41.2 years. Why is this figure so low?
9. What are some of the physical and chemical changes that occur in cells, tissues and organs as they age?
10. How does starvation of young rats increase their longevity?
11. What is juvenile hormone?
12. Do you think it possible to double man's average life span by any method?

FURTHER READING

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CHAPTER 57

Human Diseases

Man has lived on this earth for about a million years. Primitive man fought against the ravages of climate and beasts. He knew sorrow and disease but understood little of their cause. He thought that diseases were caused by demons and evil spirits.

The early healing methods were mixed up with witchcraft and magic. Trephining or boring through the skull, practised by man as early as five to ten thousand years ago, could have been to let the devil out than to repair the brain. The tribal medicine man used masks, charms and symbols to drive off the spirits of disease.

Some system of medicine was practised by the Aztecs of Mexico, Babylonians, Egyptians, Hebrews, Chinese, Hindus and Arabs. The History of medicine is a long process of trial and error.

The greatest of the ancient medical men was Hippocrates, a Greek physician. Many students studied medicine under him. They took an oath to live and practise medicine with a high moral standard. Hippocrates was the first person to write detailed descriptions of disease symptoms and emphasize the need for good diet, fresh air and rest. He separated medicine from religion, superstition and philosophy. He showed that the human body has a natural tendency to rid itself of the disease. Hippocrates also wrote on the setting of fractures and healing of wounds. He was a great man and deserves to be called the 'father of medicine'.

Another notable man was Galen, a Greek surgeon, who served the Romans in Alexandria in the second century A.D. Greatly influenced by Hippocrates, Galen listed many plant drugs, described the functions of the various organs, and performed surgical operations. He was a great orator and an excellent writer. His influence lasted several centuries.

After the end of the Roman civilization, Europe passed through the so-called **dark ages** till the fifteenth century. Few contributions were made to the arts or sciences. Superstition ruled human activities. Great epidemics broke out frequently. Plague alone took 60 million lives between 1347 and 1350. Disease was thought to be due to bad blood. Barbers punctured the veins of patients to let the blood out. Even leeches were made to suck blood ! The bad air of marshes was also blamed for causing fevers.

In 1676 Leeuwenhoek peeped through his microscope and saw bacteria for the first time, but it took decades to prove that they caused disease. The credit for establishing

the germ theory of disease goes to two brilliant scientists, Pasteur and Koch.

Louis Pasteur and the germ theory of disease. Louis Pasteur was a French chemist. Even as a young man he had clearly shown that germs in the fermenting liquids came from air and did not arise spontaneously. In a sample of souring sugarbeet juice, he saw under the microscope, millions of tiny rod-shaped bacteria. This observation was the beginning of great events. Pasteur showed that bacteria also caused souring of wine, beer and milk. He demonstrated to the French wine-makers that bacteria could be killed by heat. This process, called pasteurization, is used even today for preserving milk.

In 1877 Pasteur became interested in the diseases of chicken, cattle and sheep. He saved thousands of sheep by immunizing them against an infectious disease called anthrax. Pasteur's name became well known in 1885 when he found a cure for rabies. He immediately received honours from all corners of the world. He died in 1895 at the age of 73.

Fig. 57.1. Robert Koch (1843-1910), the great German bacteriologist, is renowned for his postulates to prove the causative agents of disease. Courtesy of the Embassy of Federal Republic of Germany, New Delhi.

Robert Koch and bacteria. When Pasteur was making his famous discoveries, Robert Koch was practising medicine in Germany. In 1876 he examined the blood of cattle that had died of anthrax, and found it to abound in rod-shaped bacteria. Koch was a very methodical man. He wanted to know if these bacteria were the real causes of the disease. He developed a technique of isolating and growing the bacteria in the laboratory. He injected living bacteria into a healthy mouse which contracted anthrax and died in a day. Koch then removed the bacteria from the spleen of the dead mouse and cultivated them in the laboratory. The bacteria were still capable of causing infection. This systematic investigation by Koch is acclaimed as a great achievement in science.

Koch stated that certain requirements must be fulfilled if the disease causing character of any organism is to be proved, and these are called **Koch's postulates:**

(a) The organism must be found in abundance in the body of the animal suffering from a disease.

(b) It must be isolated and grown in pure culture artificially.

(c) The same disease must be produced when the cultured organisms are injected into healthy animals.

(d) The organisms must be recovered from the infected animals.

Koch made many other valuable contributions. In 1882 he isolated the tubercle bacillus from the lungs of a patient suffering from tuberculosis, and also identified the bacteria that infect wounds. In 1883 he studied human cholera and showed how the bacteria spread through food and water. Koch can be called the greatest bacteriologist of all times. His methods have stood the test of time.

Disease and Its Spread

A disease can be defined as a disorder of the mind or body. It is opposed to health.

It is not easy to classify all the human diseases. However, they can be broadly divided into 'congenital' and 'acquired' diseases. **Congenital diseases** are present right from the birth and may result from errors in metabolism or defective body development. **Acquired diseases** are those which develop after the birth. They are grouped as follows:

(a) **Infectious diseases** caused by viruses, bacteria, protozoa, fungi and worms.

(b) **Degenerative diseases** like those of heart and central nervous system.

(c) **Deficiency diseases** due to deficiency of carbohydrates, proteins, fats, vitamins or minerals in the diet.

(d) **Allergies.**

(e) **Cancers** (new growths).

There are many ways in which a disease can spread. Germs can be spread by coughing, sneezing, through contact or improperly washed cups, plates, towels and other clothes. Food, milk and water exposed to dust and flies are common means of spreading diseases. Open wounds and cuts may also be inroads to infection. Mosquitoes, fleas, bugs, parrots, dogs, rabbits and other animals also transmit germs by bites or contact. Some individuals may act as 'carriers' of disease causing germs although they themselves do not show the symptoms of the diseases.

The organisms which invade the human body may destroy blood cells and vital tissues, use up the food materials or release **toxins** (poisons) which travel to other parts and cause damage. Toxins could be general in their action or they may kill specific tissues.

The skin protects our body against the invading microbes. The passages of the nose, throat and trachea are lined with a thin layer of cells, the mucous membrane. This secretes a slimy fluid called mucus which contains an enzyme that destroys bacteria. The membrane also has a large number of cilia. If dust particles or other foreign bodies enter the above passages, the cilia force them out by causing one to sneeze or cough. Tears in our eyes destroy and wash away micro-organisms. The acid in our stomach also kills certain germs. All these methods constitute the first line of defence.

If, however, the bacteria enter the body through injured skin, the white blood corpuscles in our blood and lymph nodes engulf and destroy them. It is during this fight that we develop a fever. This is the second line of defence. The dead bacteria and the white blood corpuscles accumulate at the wound as pus.

Our blood also produces substances called **antibodies** to fight the invading organisms. Antibodies are complex proteins and much is not known about them. A specific antibody is produced against a specific microbe.

The antibodies are of several kinds. Antitoxins neutralize specific toxins released by the germs. For example, the tetanus antitoxin is specific against tetanus toxin and not diphtheria toxin. Agglutinins cause agglutination or clumping of the invading microbes; bacteriolysins cause dissolution of specific bacteria, and opsonins prepare the bacteria to be easily engulfed by the white blood corpuscles. The antibodies against some microbes persist in the blood for several years and serve to defend any new infection. The general term **antigen** is used for any organism or its substance that causes antibody production in our body.

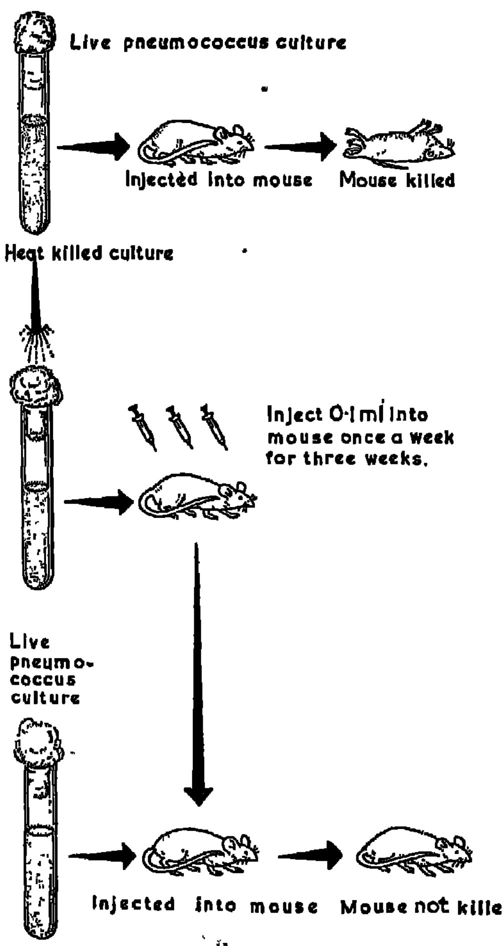

Fig. 57.2. Acquired active immunity. After W. W. Umbreit, Modern Microbiology, W.H. Freeman and Co., San Francisco, 1962.

Immunity

The resistance of our body to disease is called **immunity.** If we contract a disease we are **susceptible** to it. Human beings are immune to most of the diseases of plants or animals. This is **natural immunity.** However, tuberculosis and anthrax can be contracted from animals.

Immunity can be acquired by having had the disease once or by getting dead or weakened germs injected into our body. The preparation employed for this purpose is called a **vaccine.** The vaccine enables the body to build up its own antibodies. This is called **acquired active immunity** and lasts for a long time (Fig. 57.2).

Smallpox, polio, typhoid, cholera and plague are some of the diseases against which vaccines are commonly used. Smallpox vaccine is produced as follows: The fluid from the pox is introduced into the body of a young calf through scratches made on its abdomen. The calf develops white swellings within a week, is then killed and the infected masses are collected in sterile containers and frozen. These are later mixed with glycerine and salt and stored in sealed tubes. When a baby is to be vaccinated, the vaccine is rubbed into the arm after puncturing the skin.

Sometimes, antibodies produced by other animals are injected into the human body to give temporary protection. This is called **acquired passive immunity.** In passive immunity the body makes no antibodies of its own. The name serum is given to blood plasma containing antibodies

against a particular disease-causing organism. To produce a serum, a large animal—usually a horse—is injected in increasing doses with the toxin produced by a microbe in culture (Fig. 57.3). The horse gradually makes its antitoxin in large amounts. The main vein in the neck of the horse is punctured and the blood is drawn out into sterile containers. The serum with the antitoxins is removed and standardized. The antitoxins of diphtheria, scarlet fever, tetanus and snake antivenom are produced by this method.

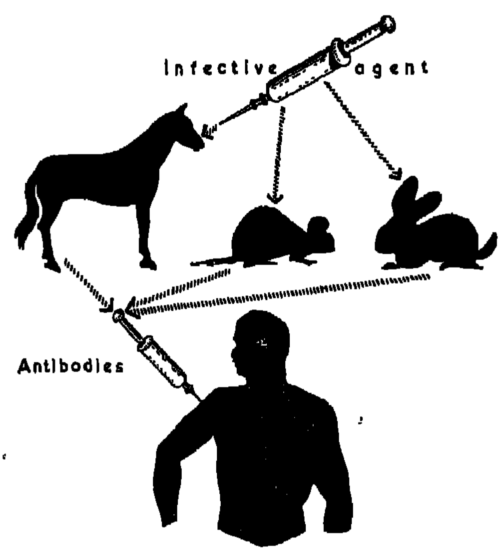

Fig. 57.3. Acquired passive immunity. The animals are inoculated with the infective agent which causes the production of specific antibodies. Blood serum containing the antibodies is taken from these animals and injected into human beings to protect them from the disease. The patient is not permanently immune to the disease since he does not himself produce the antibodies. Adapted from Paul B. Weisz, *The Science of Biology*, McGraw-Hill Book Company, Inc, New York, 1963.

We owe much of our knowledge about immunity to Edward Jenner (1749-1823), an English physician. Jenner had seen severe epidemics of smallpox and had noted the curious fact that dairymen and milkmaids rarely suffered from it. He soon discovered that the milkmaids contracted a mild disease called **cowpox** from the cattle they milked. The disease left a sore on the hands. After developing cowpox they were somehow safe from smallpox.

Jenner was curious to reproduce by an experiment what went on in Nature. On May 14, 1796, he took some fluid from the cowpox sore on the hand of a milkmaid and injected it into the arm of a healthy boy named James Phipps (Fig. 57.4). Phipps developed a typical sore on his arm but this soon healed. After two months, Jenner boldly injected some smallpox fluid into the body. The experiment was a big risk but the boy never got smallpox! Jenner was surprised. He tried again and again and every time he found that cowpox induced immunity against smallpox. Although people scoffed at this idea and thought that cowpox gave them the instincts of a cow (Fig. 57.5), they soon realized its value. Jenner vaccinated thousands of people. The British Parliament honoured Jenner with a gift of £ 30,000.

Infectious Diseases

Diseases caused by bacteria. Tuberculosis is responsible for the loss of an enormous number of lives every year, being especially common among people who live in dingy, congested parts of large cities. The bacteria of tuberculosis (Fig. 57.6) invade any part of the body, multiply rapidly and destroy the tissues. Lungs are the favourite site of infection where small tubercles are formed. X-raying of the chest will show how much of the lung has been

Fig. 57.4. Edward Jenner (1749-1825), a British physician, discovered a method of immunizing man against smallpox. Here he is seen injecting vaccine into the arm of a young boy, James Phipps. Courtesy of the British Information Services, New Delhi.

Fig. 57.5. A cartoon showing the reaction of the 18th century people to vaccination. Edward Jenner is shown using his cow-pox extract to vaccinate patients against smallpox. The cartoonist seems to have had misgivings about the results of vaccination. Courtesy of the Bettmann Archive, Inc., New York.

damaged (Figs. 57.7 and 57.8). A **sputum** (fluid from lung) **test** further helps the doctor to know how serious the disease is. The bacteria of tuberculosis release tuberculin—a toxin which causes fever, loss in weight and weakness. Fatigue, malnutrition and persistent cold decrease our resistance to the bacteria.

Until a few years ago fresh air and rest were the only remedies. Recently, however, streptomycin, PAS (para-amino-salicylic acid), isoniazid and related drugs have proved invaluable in curing the disease in its early stages. In very advanced cases of tuberculosis the removal of the infected part of the lung or its temporary collapsing

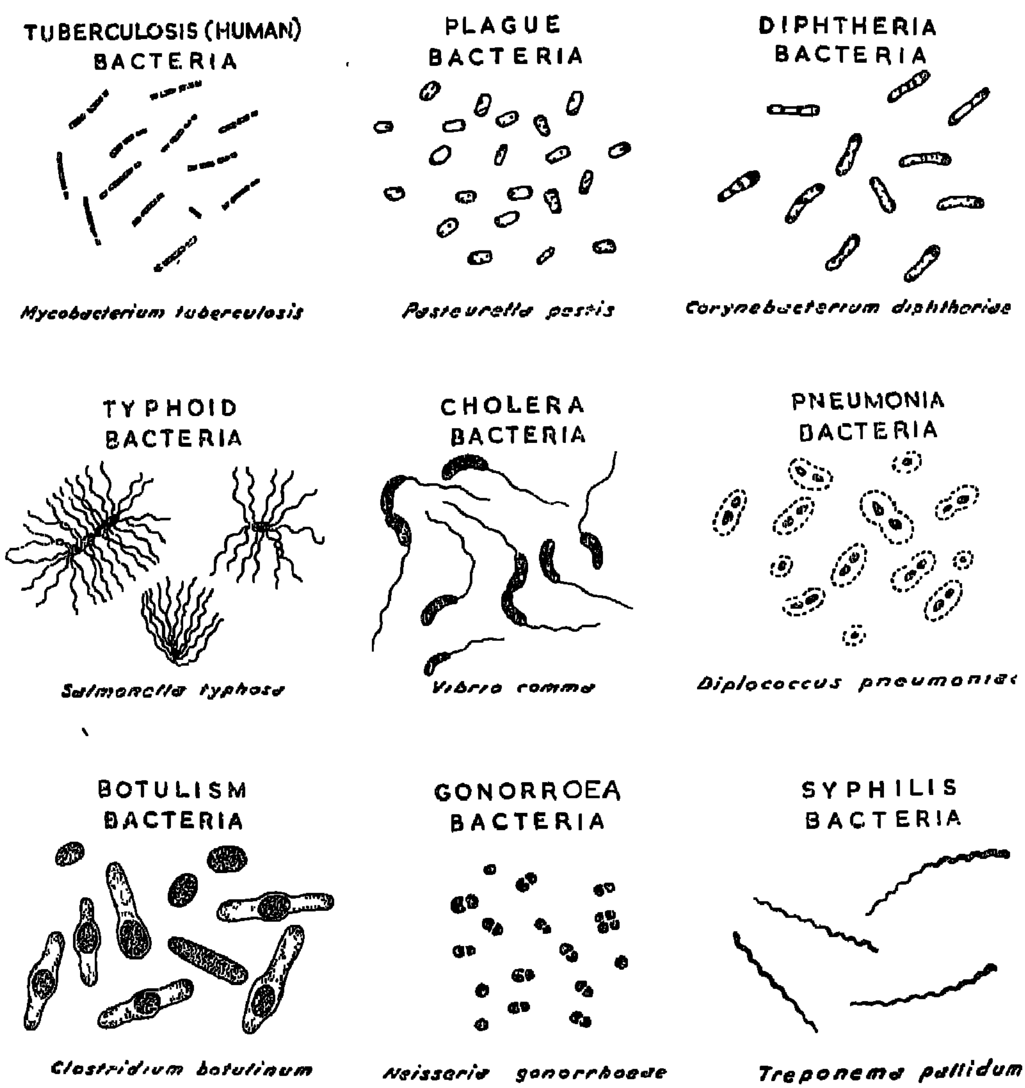

Fig. 57.6. Bacteria which cause some common diseases of man. After W. G. Walter and R. H. McBee, *General Microbiology*, D. Van Nostrand Co., Inc., Princeton, New Jersey, 1962.

Fig. 57.7 A patient preparing for the X-ray test. The frame against his chest contains the photographic film. The X-rays (see the source on the left) pass through the softer parts of the body without much obstruction, but the bony parts offer resistance. This produces the familiar X-ray picture. Courtesy of the United Nations Health Service.

is practised. To check the spread of the disease it is important that every patient is located and treated. Various government and private organizations are working for the eradication of tuberculosis in India. The money you pay to buy T.B. seals is spent for this purpose.

Plague is another notorious disease which took millions of lives in the past. This 'Black Death' or 'Great Mortality' occurred in Europe in an epidemic form in 1348, and reduced the population to one-third. Plague was brought to India in 1895 by ships calling at Bombay from Hong Kong, and killed 1,300,000 people in 20 years. It was in India that the details of plague transmission and control were studied.

Plague is caused by a rod-shaped bacterium (Fig. 57.6) which parasitizes the fleas that occur on rats, mice, squirrels and other rodents. The disease is transmitted from rat to rat by the blood-sucking fleas. Man gets the fatal disease by flea bites or

Fig. 57.8. X-ray photograph of a patient suffering from tuberculosis. His right lung (shaded) is normal whereas the other lung is affected (white area). Courtesy of the Patel Chest Institute, University of Delhi.

during accidental contact with infected rats. Plague is of three types: pneumonic (affecting lungs), bubonic (formation of swellings in the groin, armpits and other places), and septicaemal (destruction of red blood corpusceles). The extermination of rats, killing of fleas by DDT, use of vaccine, sulpha drugs and streptomycin have controlled plague remarkably, and it is no longer a dreaded disease.

The disease called **diphtheria** especially attacks children. The bacteria (Fig. 57.6) grow in a membrane on the wall of the throat and block the air passage by their excessive growth. The toxins cause weakness, high fever, and damage to the heart and nervous system, and death occurs due to choking.

Leprosy is a chronic infection of the skin and other tissues including the nerves. It is prevalent mostly in Africa and Asia. Ulcers, nodules, scaly scabs, deformities of fingers and toes, and wasting of body parts are the usual symptoms. At places of pilgrimage in India it is a common sight to find flocks of lepers begging for alms. The disease is communicated only after long and close contact with infected individuals. Children isolated from leper parents early in life grow into normal and healthy persons.

Typhoid is an acute infection of the intestines. The bacteria (Fig. 57.6) damage the intestinal wall, cause fever and weakness. The fever lasts two or three weeks and it may relapse when other parts of the body like bone marrow, spleen or gall bladder are infected through the blood stream. Death may occur due to haemorrhage or puncturing of the intestines. A new drug—chloromycetin—is effective in controlling the disease. **Gastroenteritis** is another intestinal disorder fairly common in India, and is caused by a bacterium closely related to the typhoid bacterium.

Cholera exists in several forms. The type called **Asian cholera** has persisted in this country since thousands of years and breaks out periodically. The cholera bacteria (Fig. 57.6) spread through contaminated food, and cause violent diarrhoea, vomiting and muscular cramps. The fatality rate of infected persons used to be 30-50 per cent. Cholera epidemics still break out frequently in this country during fairs and festivals.

Pneumonia is a group of diseases of the lungs in which the tissues become inflamed and watery resulting in fever and breathing difficulties. It attacks people of all ages and is a major communicable disease. Many human carriers harbour the bacteria (Fig. 57.6) in the nose or throat without evidence of the disease. Viruses also cause pneumonia. Antibiotics and sulpha drugs have successfully conquered the disease.

There is a kind of food poisoning which develops by eating inadequately sterilized meat, vegetables and fruits. This is called **'botulism'.** The bacteria (Fig. 57.6) gain entry into the cans, multiply in the absence of air, and release a powerful poison which is very toxic to the nervous system. Vomiting, double vision, heart failure and respiratory troubles appear after 24 hours of feeding. Heating of the canned foods before eating destroys the poison.

or V.D.

Gonorrhoea is a venereal disease resulting from an infection of the mucous membranes of the urinogenital tract. The disease causing bacteria (Fig. 57.6) spread by direct contact, usually sexual intercourse with an infected person. The infection spreads from the genitalia to other parts of the body and may cause arthritis (inflammation of joints) and female sterility. Children born to affected mothers often suffer from eye infection. The sulfanomides

Fig. 57.9. Sir Ronald Ross, an English army doctor who while serving in India discovered the complete life cycle of the malarial parasite.

and antibiotics are useful against gonorrhoea.

V. D

Syphilis is another venereal disease caused by a cork-screw-like bacterium (Fig. 57.6). Transmission is through sexual contact or contaminated objects. The disease affects numerous parts of the body with varied symptoms. It can be transmitted from mothers to the new born babies. There are reliable blood tests to detect the disease.

Diseases caused by protozoa. Malaria has been one of the oldest and most destructive enemies of mankind. It was accepted in the past as a calamity of the low lying swamps and marshes, and as caused by foul air. Even now nearly two and a half-million people in the world die of malaria every year. The disease leaves a patient weak and inactive and decreases his resistance to other microbes. Babies are the worst hit. Nearly 10-15 per cent of deaths (of new born babies) in the tropics are due to malaria.

For hundreds of years malaria remained a mysterious disease. In 1880 a French Surgeon named Laveran, stationed in Algeria, discovered the cyst-like protozoan parasite called *Plasmodium* in the red blood cells of a patient. He had also observed flagellate bodies being extruded from the cysts. Although Manson, a famous London physician, had believed that the mosquito has some role to play in malaria, it was Ronald Ross, a British Army doctor, who proved it. While working in India, Ross showed that the sexual part of the life-cycle of the malarial parasite occurs in the stomach of the mosquito. He demonstrated that the sporozoites are injected into the blood through saliva when the mosquito bites a healthy person. Ross was awarded a Nobel Prize for this work in 1902.

It is a habit with the mosquito that after sucking human blood it sits on the walls of the room. Spraying the walls with DDT kills the insects. Breeding of mosquitoes can be controlled by drying ditches and puddles, improving sanitation, and by spraying a thin film of oil over water in ditches. In large plantations where water stagnates, aeroplanes are used for spraying. Due to the excellent efforts of the World Health Organization (WHO) and the National Malaria Eradication Programme (NMEP), malaria has at least been tamed, if not fully conquered in this country.

Sleeping sickness or trypanosomiasis and amoebic dysentery are the other common diseases caused by protozoans.

Diseases caused by viruses. By the end of the nineteenth century numerous disease-producing bacteria and protozoa had been discovered. However, organisms causing measles, mumps, polio and common cold still evaded the bacteriologist.

In 1892 a Russian botanist, Dmitri Iwanowski, showed that the juice of a tobacco plant suffering from the mosaic disease could infect a healthy plant even after passing through an ultra-fine filter which would hold back bacteria. The disease-causing organism was a virus which was small enough to pass through the minute pores.

By 1898 the **foot-and-mouth disease** of the cattle was shown to be due to a tiny spherical virus. You will now learn about some of the important virus diseases of man.

Smallpox is perhaps the most dreaded of all the virus diseases. A highly contagious and fatal disease, it recurs periodically in our country. India is the biggest depository of smallpox, and accounts for 75 per cent of the cases in the world. As recently as 1950, over 2,50,000 people died in a single epidemic of smallpox.

The disease is recognized by pustules all over the patients' body (Figs. 57.10 and 57.11) accompanied by high fever. Those lucky enough to survive have permanent pock marks on their faces. Occasionally smallpox may result in total blindness. Smallpox vaccine is given to babies almost as a routine, which insures protection against the disease for many years. But vaccinating 40,000 babies born everyday in our country is no easy job. Due to ignorance, indifference, superstition or religious belief, even today a large number of people in this country fail to get their children vaccinated for smallpox.

You might be interested to know that unless you have an **International Health Certificate** which shows that you have been vaccinated for smallpox and cholera, you will not be permitted to enter a new country. Perhaps you will realize why such health measures are strictly enforced.

Influenza or **flu** is a rapidly spreading respiratory disease. Ancient astrologers thought that it was caused by the bad 'influence' of the stars. The disease causes fever, weakness, muscular pain, inflammation of the mucous membranes of the respiratory passages, and occasional intestinal trouble.

Epidemics of new types of influenza break out periodically. These are caused by virus mutations. The 1918 pandemic killed some 20,000,000 people throughout the world and the recent **Asian Flu** (1957) affected thousands of people all over India. One serious danger of influenza is that the patient becomes highly susceptible to other diseases like bronchitis and pneumonia.

Polio or **poliomyelitis** is a very ancient disease (Fig. 57.12). The polio virus is one of the smallest known (10 mμ in diameter) viruses. It enters the body through food or water, multiplies in the cells of intestinal wall, and the infection spreads to the lymphatic system and the blood stream. On reaching the central nervous system, the virus destroys the dorsal horn cells of the spinal cord which control the activities of the muscles. Without nerve impulses the muscles fail to work, and shrink. Thus the limbs become paralysed. If the legs become atrophied, the patients cannot walk without support (Fig. 57.13). When the respiratory centres of medulla of the brain are destroyed by the virus, the nervous impulses to the diaphragm are stopped and breathing

Fig. 57.10. **A young victim of smallpox in early stages.** Courtesy of the World Health Organization, New Delhi.

Fig. 57.11. **An acute case of smallpox. Note the severe eruptions all over the body.** Courtesy of the Infectious Diseases Hospital, Delhi.

fails. A patient then needs an 'iron lung' for artificial breathing.

The incidence of polio is less common in the tropical and subtropical countries where children get a mild infection early in life, and therefore acquire immunity. For years scientists struggled to produce a vaccine against this unfortunate disease. In 1949 Enders and his colleagues at Harvard University in the USA cultured the polio virus on pieces of monkey kidney tissues grown in a liquid nutrient medium. Following this method Jonas Salk, of the University of Pittsburgh, grew a large quantity of the polio virus in 1953. Salk killed the virus with formaldehyde, so that on injection it was incapable of causing polio. The killed virus is now popularly called Salk vaccine. With the use of this vaccine, the number of polio cases dropped by 90 per cent in the USA alone. In 1954 nearly 1,830,000 children were given injections. Recently, three Americans—Sabin, Koprowsky and Cox—independently produced a vaccine containing the live but tamed virus. The advantage of the live virus vaccine is that it can be swallowed as a pill so that the discomfort of pricking and the need for a huge staff of nurses and doctors is avoided. The 'oral' vaccines have been used all over the world with great success. The Sabin vaccine is being made on a large scale and is also being distributed in this country.

Fig. 57.12. This Egyptian engraving, nearly 3,500 years old, shows a young man with a withered leg, that is characteristic of polio. Courtesy of the Carlsberg Glyptothek, Copenhagen, Denmark.

Rabies or **hydrophobia** is another dreadful disease transmitted to man by the bite of mad dogs. The virus first stimulates and then destroys the cells of the brain and spinal cord. The patients die a painful death following restlessness, choking, convulsions and inability to swallow even liquids. The treatment of rabies is one of Pasteur's greatest contributions to mankind. He demonstrated that the seat of infection was the brain. He could transmit rabies to healthy dogs

Fig. 57.13. A young polio patient trying out leg braces. Courtesy of the United Nations.

or rabbits by injecting infected brain tissues. Pasteur also found that on drying the isolated spinal cord of the rabid dog for 14 days the virus gradually lost its activity. He saved the life of a boy named Joseph Meister, bitten by a rabid dog, by a series of injections of spinal cord tissue of a rabbit, which had been artificially infected with rabies virus. The injections induce the formation of antibodies in the patient. The same treatment is given even today, but the virus is grown in the eggs of ducks.

An acute disease called **mumps,** which usually attacks children, is characterized by the swelling of the salivary glands and high fever. The temples enlarge and the movement of the jaw becomes difficult. In adults, testes and breasts may also become inflamed.

Measles is also a common childhood disease. Skin eruption, fever, and inflammation of the mucous membrane of nose are the typical symptoms. Patients are likely to contract pneumonia as a secondary infection. Chickenpox is another virus disease which closely resembles measles.

Familiar to the ancient mariners as **'yellow jack',** the **yellow fever** disease was dreaded until recently in Southern and Central America, West Indies and West Africa. Spread by a

Fig. 57.14. Jonas Salk (1914–), an American scientist, who first perfected the technique of growing polio virus in bulk, and used the killed virus as antigen. Courtesy of the United States Information Service, New Delhi.

Fig. 57.15. Left. A young girl suffering from trachoma. Right. The same patient 10 days after treatment with aureomycin ointment. Courtesy of the World Health Organization.

mosquito, *Aedes aegypti*, the disease causes high fever, jaundice and vomiting.

Trachoma is a virus disease of the eyes (Fig. 57.15) which results in swelling, discomfort and running eyes. In acute cases it can lead to blindness. Nearly one-sixth of the world population suffers from trachoma. Antibiotics have been successfully used for curing this disease.

Degenerative Diseases

The great progress in medicine and the vast improvement in public health have considerably reduced the number and incidence of infectious diseases in all progressive countries. The death rate in children has fallen, and more and more people are reaching the age of 50 to 70 years. However, diseases of old age are becoming more frequent. These are called degenerative or 'modern diseases'.

Diseases of the heart. In the USA alone heart diseases take 900,000 lives every year. They are of four kinds: (1) **athero-sclerosis** or hardening of the arteries, (2) **hypertension** or high blood pressure, (3) **coronary heart diseases,** and (4) **rheumatic heart.**

In atherosclerosis, the arteries and the arterioles become narrow and lose their elasticity due to thickening of the fibrous tissue or the deposition of cholesterol or calcium. **Cholesterol** is a fatty substance

present in eggs, meat, butter, ghee, and cheese. In advanced stages of athero-sclerosis the rise in blood pressure may cause the arteries to rupture and let out blood. If this happens in the brain, partial paralysis occurs and the person is said to have had a 'cerebral haemorrhage'.

When persons suffer emotional stress (fear, worry, anxiety, and even excessive joy) and nervous tension, the walls of the arteries contract and the blood pressure rises. Frequent stress causes persistent high blood pressure. This is called **hypertension** and the muscles of the heart have to work harder to pump the blood. Destruction of the arteries of the kidneys, a condition known as 'chronic nephritis', is a common result of hypertension.

Blood is supplied to the heart by the coronary arteries, which fit over it like a crown. If they become hardened and narrowed, the heart does not receive enough blood. The person feels severe pain in the chest and along the arms. Nitroglycerine tablets relax the coronary arteries and reduce the pain. Occasionally, however, the blood clots and blocks an artery. This shuts off the blood to the heart and the patient has a 'heart attack', which is technically called 'coronary thrombosis'. Some patients die during the first attack while others may lead a normal life even after one or two attacks. Anti-coagulants like heparin and dicumarol prevent the clotting of blood and promote its flow.

Children usually have sound hearts. However, in some cases of bacterial infection (pneumonia, streptococcus infection of the throat) the toxins released by the bacteria travel to the joints and cause rheumatic fever (swelling and pain in the legs accompanied by fever). The valves between the auricle and ventricle become inflamed and do not work efficiently. The result is a lowering of blood pressure, and the heart is said to be 'rheumatic'. Adequate rest is advised in this condition.

Cancer. As we grow up, most body cells stop dividing. Only the cells in the bone marrow, cornea, skin, and gonads keep on dividing. This is mainly to replace the worn-out cells. Cancer results from an uncontrolled division of certain cells to produce lumps or tumours. These lumps are not painful in the beginning and may not attract attention. They are more common in old people, although they have ceased to grow. Over two million people die of cancer every year in the world.

Some growths are benign or harmless, but cancer is a malignant growth. It ruptures the vital organs and disrupts their functions. Parts of the tumour often break off, move through the blood stream or lymph to other parts of the body, and start new or secondary tumours. Death results from digestion of normal tissues and wasteful metabolism.

What makes certain cells become cancerous is not known. In fact, we know very little about what controls even normal cell division. In plants and birds, viruses have been shown to produce certain types of cancer. There is no evidence, however, that human cancers are caused by viruses. Cancer can be produced by continuous friction or long exposures to ultraviolet light, heat, or contact with certain chemicals. According to the latest reports cigarette smoking increases the incidence of lung cancer.

Blood cancer.

Leukemia is the cancer of the blood in which an excessive number of white blood corpuscles are produced. Death can occur within weeks and there is no known remedy for it.

Fig. 57.16. Photograph of a child suffering from 'kwashiorkor' (African name of the disease) resulting from protein deficiency. If a child is kept exclusively on a diet of starchy food such as rice, maize, bananas or sweet potatoes, he is almost certain to suffer from this disease. This can be remedied if the diet is supplemented with protein. Courtesy of the World Health Organization.

Although numerous scientists have been engaged in the study of cancer, there is so far no sure remedy. Surgery and treatment with X-rays, radium, radio-active isotopes of calcium and phosphorus are suggested methods of control of the disease during early stages. In later stages these methods are usually ineffective. Thousands of chemicals are being tested every year for anti-cancer activities.

Deficiency Diseases, Allergies and Other Causes of Death

Some diseases are direct consequences of the lack of certain substances in our food. A diet poor in protein results in a condition called **'kwashiorkor'** which retards the normal growth of infants. This is especially common in Central America, Africa and tropical Asia. The affected children have bulging eyes, protruding bellies, and thin 'match-stick' legs. The skin shows ugly eruptions (Fig. 57.16). Do you know that today over a 100 million children are suffering from this hidden hunger in the world?

Vitamins are another group of organic compounds without which growth is highly abnormal. For a long time people in the Far East Asia knew of a disease called **beri-beri.** The patient has tender muscles and painful weakness in the legs. We now know that beri-beri is caused by the deficiency of vitamin B_1, a member of the group known as vitamin B-complex. Scurvy, a disease from which the sailors of the past suffered on long voyages, is caused by the deficiency of vitamin C. The skin becomes dry and the gums start decaying. **Rickets,** which results in the deformity of bones, is due to the deficiency of vitamin D (Fig. 57.17). The deficiency of vitamin A can cause night-blindness. In Indonesia one in every 100 children suffers from this disease.

Pellagra, a disease caused by the lack of niacin, is peculiar in that the patient develops rose-like marks on the body. Lack of iron results in anaemia; iron is needed for the

Fig. 57.17. A child suffering from rickets. Note the bow legs and the widened wrist. Courtesy of K.L. Wig, All India Institute of Medical Sciences, New Delhi.

manufacture of red blood corpuscles. Lack of iodine results in goitre (swelling of thyroid glands) and cretinism. In Ecuador (South America) nearly 70 per cent of the people suffer from goitre.

Allergies are a group of non-infectious diseases which are not usually fatal but annoying and miserable. These result from the hypersensitiveness of certain individuals to foreign matter, which may be made of protein or polysaccharide. While the list of allergens is long, the most common are caused by pollen, feathers, dust, emanations of cats, dogs, and other animals, silk, wool, and drugs like quinine and horse serum.

In an allergy the mucous membranes of the nose, throat and trachea become irritated. Sneezing, sniffing, gasping and running eyes develop within minutes of contact with allergens. In some cases the skin becomes erupted and itchy. This condition may last a few hours or several years !

You must have seen some old people suffering from asthma. This is also a form of allergy. Another is hay fever caused by inhaling pollen of certain grasses and other plants. This allergy can be correlated with the flowering season of some weeds.

Apart from the diseases described above, there are numerous others like the diseases of the central nervous system, deficiency or toxicity of secretions of endocrine glands, and hereditary troubles. Fire hazards, earthquakes, floods, famines, murders, suicides, drug addiction, alcoholism and accidents also take a heavy toll. Their control still remains a challenge.

Conquest of Disease

Chemotherapy: sulpha drugs and antibiotics. Although primitive man blamed demons for disease, he quietly went about trying plants, animal products and minerals for relief. After long trials and errors he gradually came to know the potential value of some of these as drugs.

The ancient Peruvians used the bark of *Cinchona* plant against malaria long before Columbus discovered America. The Spanish explorers and Jesuit missionaries brought this wonder bark powder to Europe. So expensive was this drug that only kings and nobles could afford it. Two Frenchmen isolated a compound called quinine from the yellow-barked *Cinchona*. This was several times more powerful than the whole bark. During world wars I and II the supply of the bark fell short and, therefore, new and better anti-malarial drugs were developed

out of necessity. Atabrine, pentaquine and chloroquine are some examples.

For thousands of years the people of India had been using the 'Sarpagandha' (*Rauvolfia serpentina*) for high blood pressure, sleeplessness, madness, intestinal troubles, and a score of other ailments. A drug called reserpine was isolated from the roots of this plant less than 10 years ago. It is very effective in reducing blood pressure and is a popular drug in the market.

Chemists have isolated hundreds of pure drugs from various other plants. Morphine, strychnine, digitalin, cocaine, emetine, ergometrine and atropine are a few important ones.

The first chemical which could specifically cure syphilis like a magic bullet was a substance called '606'. It was after a gruelling trial of 605 compounds that Paul Ehrlich (1910) found this substance and hence the name 606. It was an arsenic compound and was later named 'salavarsan'. Chemotherapy, a new science in the service of healing, took its birth.

Till about 1935, all the known drugs were effective mostly against the protozoan parasites, and the diseases caused by bacteria were almost incurable. In 1935, Gerhard Domagk, a German scientist, showed that a brick-red dye 'prontosil' dramatically killed streptococci (spherical bacteria which join like beads to form a string) when injected into mice. Domagk tried the dye successfully on his own daughter who had an incurable infection. It was found that within the patient's body the dye became converted into sulphanilamide, a new compound containing sulphur. Chemists became thrilled, and soon numerous other sulpha drugs were produced. These are still in use against pneumonia, tonsilitis, meningitis, gonorrhoea, and infections of the intestines and urinary tract. Deaths due to pneumonia alone dropped to one sixth.

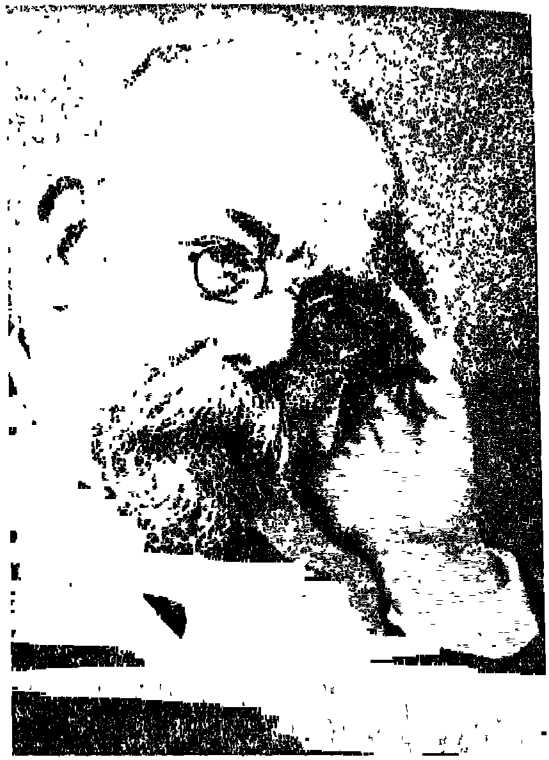

Fig. 57.18. Paul Ehrlich (1854—1915), a German scientist, who is credited for initiating modern chemotherapy—the practice of killing pathogenic organisms by the use of specific chemicals. Courtesy of the Embassy of the Federal Republic of Germany, New Delhi.

More recently, a group of chemical substances called antibiotics has revolutionized medical treatment. The word **antibiotic** means 'against life' and refers to toxic substances produced by one micro-organism against another. Pasteur had observed that some microbes destroy other microbes. He believed that if man could find organisms that would kill the disease-causing microbes, many diseases could be easily controlled.

The real start in the history of antibiotics was made by a chance observation of Alexander Fleming (1881-1955), an English bacteriologist of St. Mary's Hospital in London. On a September morning in 1928, Fleming found that a bluish mould had trespassed into a petridish in which he was culturing *Staphylococcus aureus*, the bacterium which causes boils. Colonies of bacteria close to the mould were killed while those farther away were quite healthy. The trained eye of Fleming realized the significance. Here was a warfare between one organism and another. The mould was isolated and identified as *Penicillium notatum*, a common green fungus which occurs on moist bread, leather, and orange peels. From a large quantity of the culture broth of this mould, a small amount of a substance called penicillin was obtained. This inhibited microbes powerfully. However, Fleming could not extract penicillin from the mould in sufficient quantity and gave up this difficult task.

Fig. 57.19. Alexander Fleming (1881-1955), the English bacteriologist who, discovered penicillin. Courtesy of the British Information Services, New Delhi.

World War II broke out in 1939, and the British doctors were looking for an antibiotic to treat infections and diseases. In 1940, after a hard work of several months, Howard Florey and Ernest Chain of Oxford University concentrated penicillin and demonstrated its marvellous healing properties. The amount of penicillin manufactured was not sufficient even to treat a few patients. Due to the combined efforts of the scientists, the US Government, and the drug makers, penicillin began to be produced in gigantic tanks instead of milk bottles, and was made available to the whole world. Fleming, Florey and Chain were jointly awarded Nobel Prize in 1945.

Penicillin is a house-hold name today and does not cost very much. It is effective against many diseases like pneumonia, diphtheria, anthrax, tetanus, syphilis, gonorrhoea and meningitis. In India penicillin is manufactured (Fig. 57.20) at Pimpri near Poona and in Baroda.

Although penicillin is a magic drug, it is not effective against all diseases. After many years of routine testing, several other antibiotics such as streptomycin, chloromycetin and aureomycin have been discovered.

Today the antibiotics are being used not only against infectious human diseases, but also in treating plant diseases, in meat preservation, and as a supplementary feed to poultry and cattle. The antibiotics have saved millions of lives but they are not without some danger, and complications may arise by careless use. Antibiotics should, therefore, never be taken without consulting a doctor.

A B

Fig. 57.20. These photographs are from a modern penicillin factory. A. Penicillin extractor. B. Packaging of penicillin vials. Courtesy of the Press Information Bureau, New Delhi.

Modern surgery. The surgical methods practised even a hundred years ago were crude. Butchers or barbers sawed off limbs while a terrified crowd held the patient tightly. The very thought of this sends a shudder through us. Many people naturally preferred to die than to submit to such painful operations.

'Bhang' and 'ganja' (obtained from *Cannabis sativa*), opium, the root of *Mandragora*, henbane (*Hyoscyamus*), and liquor were often given to patients to diminish pain. Hypnotism or mesmerism (a kind of sleep induced by another person) or even a hard knock-out blow on the head of the patient were also tried.

For the first time in 1842, C.W. Long, a young American medical practitioner, used ether to make a patient unconscious during the surgical removal of a tumour. A new term, **anaesthesia**, was coined for the loss of consciousness brought about by inhaling ether. It so happened that the work of the small town doctor failed to attract the attention of other doctors at that time. A few years later W.T.G. Morton, a well-known dentist of Boston, USA, successfully used ether for painless extraction of teeth. He demonstrated this event before a large gathering of eminent surgeons.

With the use of the anaesthetics more and more operations could be performed without causing pain, but they were still not safe. Three out of four patients died because the wounds became infected. The operation theatres were primitive, the instruments were rusted, and the bandages and linen unwashed. The surgeon wore the same soiled clothes day after day and the nurses helped with dirty hands.

In 1860, when surgery was still cursed and feared, Joseph Lister was appointed as a surgeon at Glasgow, UK. He studied the writings of Pasteur and realized that fermentation was caused by micro-organisms present in the air. Lister thought that wound infections must also be caused by the germs in the air. He soaked pieces of cloth in carbolic acid and placed them on the wound. The wounds healed without sepsis since

carbolic acid killed the germs. He also instructed that the hospital floors, walls, instruments, clothes, and the hands of doctors and nurses were to be thoroughly cleaned with carbolic acid. Thus, Lister introduced **antiseptic surgery.**

Those days of painful surgery and fear are gone. We have several kinds of anaesthetics today. Ether and chloroform are inhaled, others are injected into the spinal column or a vein, and still others are sprayed. General anaesthetics have an effect over the whole body, while local anaesthetics prevent pain in a small area.

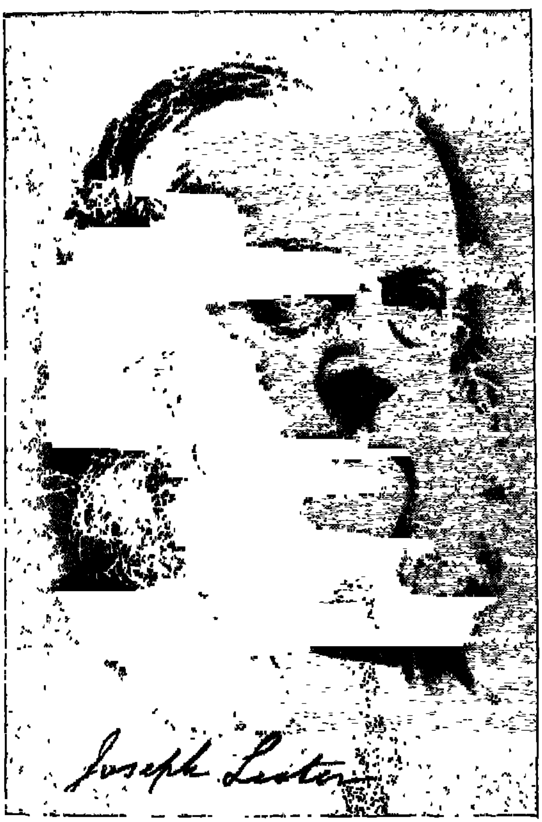

Fig. 57.21. Joseph Lister (1827-1912), the celebrated English physician, who started antiseptic surgery by the use of carbolic acid. Courtesy of the British Information Services, New Delhi.

Asepsis is now practised in almost every hospital (Fig. 57.22). Disinfectants like phenol (dilute carbolic acid), lysol, and commercial products like dettol and listerine are used for cleaning. During your visit to some hospital you might have noted a typical smell. Instruments, gloves, bandages, gowns, head covers and face masks are sterilized in steam under pressure. Special sterilizers called 'autoclaves' are used for this purpose.

Anaesthesia has now become a routine. Surgery has advanced tremendously and the benefits of skin grafting, surgical repair of heart, brain, kidneys, and eyes have recently been provided for a much larger number of patients.

Nuclear medicine. Roentgen, a German physicist, discovered X-rays in 1895. They have the unique property of penetrating opaque or solid tissues of the body. Due to their differential absorption, a permanent picture can be obtained by placing a photographic plate behind the object. X-rays are widely used for study and diagnosis of conditions such as fractures, intestinal obstruction, tuberculosis and bullet wounds.

Elements like iodine, phosphorus and gold can be made radioactive when they give off invisible but highly penetrating rays. Radioactive materials may be introduced into the body along with non-radio-active elements. By studying the path of movement of radioactive compounds in the body, one can understand how the body organs are functioning. Radioactive elements kill diseased as well as normal tissues, and treatment of cancer is one of the main benefits of nuclear medicine.

Fig. 57.22. Surgery in the present times. A. General set up of a modern operation theatre. Note the operation table and the numerous instruments used for anaesthesia, blood transfusion, artificial respiration and other treatments. B. A patient being given anaesthesia. C. Doctors attending on an operation—a long way from the days of Lister. D. Blood transfusion. Courtesy of K.L. Wig, All India Institute of Medical Sciences, New Delhi.

Conclusion

You have read in this chapter how in the past diseases struck man terribly, and caused death and devastation. It was less than a century ago that bacteriology took its birth. If we hope to reach a greater age today, we have to thank thousands of scientists for their insight, toil and devotion in combating the scourges. Some of the daring scientists who were dealing with the deadly germs lost their own lives in their efforts. You will also

be impressed how minute organisms, which are not even visible to the naked eye, can endanger man, the supreme living being. Prevention of disease is important. It is your obligation as an educated person to follow the principles of hygienic living. Our misery is not so much due to hunger or poverty; it chiefly stems from the general lack of intolerance of filth and flies. In 1950 the annual death rate per 1,000 Indian citizens was 16.1. Eleven out of these died of diseases. By 1959 the death rate fell to 9.9. Deaths due to diseases have been reduced nearly by half. Progress can come only by applying scientific principles to our every day living. We have the know-how but a lot still needs to be learnt, and done. Education, trained biologists, and money are needed to relieve mankind of its diseases.

SUMMARY

Primitive man thought that demons and evil spirits caused the diseases. Masks, charms and witchcraft were used to rid oneself of the disease. The real causes of the diseases remained unknown for long. During the dark ages severe epidemics broke out and took millions of lives. Man could not check their ravages.

The invention of the microscope was a great landmark in the history of biology and medicine. In 1683, Leeuwenhoek saw bacteria under the microscope for the first time. A French chemist, Pasteur uprooted the theory of spontaneous generation, and proved that fermentation was caused by microorganisms. He showed that heat killed the germs. He immunized sheep against anthrax, and found a cure for rabies. Koch, a German doctor, isolated the anthrax bacteria and cultured them artificially. He induced anthrax in a healthy mouse by infecting it with pure cultures of anthrax bacteria. His methods of establishing the causal organism of a disease are works of a great scientific mind.

The diseases that afflict man are numerous. Some are present right from our birth; others are acquired in our life time. Infectious diseases are caused by viruses, bacteria, protozoa, fungi and worms. Diseases of the heart and nervous system develop chiefly due to the degeneration of tissues. Deficiency diseases, cancers, allergies and injuries are the other major diseases. The three main inroads to infection are the respiratory tract, intestines and wounds. Germs are carried along with dust, food, milk and water or by direct contact, flies and mosquitoes.

The invading germs destroy blood cells, tissues and organs, and release toxins. The body fluids like mucus, tears and acid in our stomach destroy the germs. If the germs enter the blood stream, they are engulfed by the white blood corpuscles. Our blood also prepares antibodies to fight the antigens released by the microbes.

The resistance of our body to disease is called immunity. Immunity may be acquired by having had the disease or by injecting dead or weakened germs (smallpox, polio, typhoid, cholera) into our body. This is called vaccination. Temporary protection against a disease may be given by injecting a serum containing antibodies (diphtheria, tetanus) prepared by other animals.

We owe a great deal to Edward Jenner, an English doctor, for our understanding of the idea of immunity. Jenner had observed the curious coincidence that dairy men who had contracted cowpox from cattle were somehow immune to smallpox. Jenner tested this observation by injecting the fluid from a cowpox patient to a healthy boy and reinfecting him with material from a smallpox patient. The boy had developed immunity to smallpox. This little experiment of Jenner started man's first battle against the microbes.

Tuberculosis or white plague is a miserable bacterial disease common among underfed and overworked people living in dingy, congested parts of large cities. Loss in weight, cough, fever and fatigue are the common symptoms. Plague is the notorious 'Black Death' which killed nearly a third of the population of Europe in 1348. Diphtheria, typhoid, cholera, pneumonia, tetanus, botulism, gonorrhoea and syphilis are the other serious bacterial diseases.

Malaria is an old scourge of mankind. It is spread by the blood-sucking, female anopheles mosquito. The disease persists for years and leaves the patient weak and inactive. The control of malaria requires, location and the treatment of every patient, killing of mosquitoes by insecticides, drying of puddles to prevent mosquito breeding and the use of anti-malarial drugs.

The viruses being too small to be seen even under a compound microscope, have been problematic. The proof that viruses cause diseases came only recently. Smallpox, measles, mumps, rabies, yellow fever, influenza and polio are the major virus diseases. Victims of polio may die due to failure of breathing or if they survive, they are crippled for life. Salk prepared polio vaccine (given by injection) in 1953 by culturing the virus on pieces of monkey kidney. More recently Sabin, Cox and Koprowsky have independently prepared a live polio vaccine which can be taken orally.

With improvement in general hygiene and the discovery of antibiotics, the infectious diseases have been tamed. However, diseases of the old age, like those afflicting the heart and the nervous system have become more frequent. High blood pressure, atherosclerosis, coronary heart diseases and rheumatic heart are claiming thousands of lives each year.

Uncontrolled divisions of certain mature cells of the body lead to cancers. These rupture the vital organs and destroy their functions. Parts of the tumour break off, move to other parts of the body and start new tumours. Heat, radiation, friction, chemicals and even cigarette smoking are known to stimulate cancer production. Some cancers can be treated at early stages. Delay in treatment of cancer can be fatal.

Lack of carbohydrates, proteins, fats, vitamins or minerals in our diets leads to abnormal growth and development. Allergies result from hyper-sensitiveness of some individuals to various protein or polysaccharide-containing compounds.

Guided by instincts, man sought remedies for his diseases in plants, animals and minerals around him. The science of healing developed after a long process of trial, error and learning. *Cinchona* and *Rauwolfia* are two valuable drugs used by the ancient peoples, and find a wide use even today. In 1910 Paul Ehrlich tested an arsenic compound which acted as a magic bullet against syphilis. In 1935 came the sulpha drugs which reduced the cases of bacterial diseases by half.

A revolution in medical treatment occurred by the intelligent use of a chance observation of Alexander Fleming. He saw that a substance produced by *Penicillium*, a green mould, had destroyed bacteria growing in the same petridish. The word antibiotic ('against life') was later coined to suggest this effect.

A hundred years ago more than half the number of patients who received surgical treatment died of horror, pain or infection. In the middle of the 19th century, Long and Morton in the USA used ether to relieve pain during operation. About the same time Joseph Lister introduced aseptic surgery by the application of carbolic acid on dressings, instruments and hands of doctors. X-rays, discovered by Roentgen in 1895, proved a valuable tool to diagnose fractures, tuberculosis, bullet wounds and intestinal obstructions. Radioactive elements help us in understanding the functioning of body organs and in treating cancers.

QUESTIONS

1. What are the outstanding contributions of Hippocrates, Galen, Pasteur, Koch and Lister?
2. What is a disease? Classify the various diseases.
3. List Koch's postulates.
4. In what three ways does the human body defend itself against a disease?
5. What are antigens, antibodies, vaccine and serum?
6. What antibodies do you have in your blood?
7. Define immunity. Distinguish between acquired active immunity and acquired passive immunity.
8. Recall Jenner's experiment on James Phipps. What is the significance of this experiment?
9. Name any two insects that spread diseases.
10. What are the three danger signals of tuberculosis?
11. Tetanus occurs only as a result of deep wounds. Why?

12. Plague and smallpox are unlikely to occur in our modern cities today. Why?

13. Why is malaria more common in marshy areas than in dry places?

14. What is the contribution of Ronald Ross to humanity?

15. How does the spraying of walls with DDT help prevent malaria?

16. That viruses cause human diseases is a fairly recent discovery. Were there no viruses say, a hundred years ago?

17. How does polio virus enter the human body?

18. How are limbs paralysed as a result of polio infection?

19. Describe how polio vaccine is produced.

20. What are the advantages of live polio vaccine over the killed vaccine?

21. How did Pasteur save the life of a boy bitten by a mad dog?

22. What is a 'heart attack', a 'cerebral haemorrhage', and a 'rheumatic heart'?

23. What is the difference between coronary thrombosis and cerebral thrombosis?

24. What are anti-coagulants?

25. How do cancers endanger life?

26. How are patients treated for cancer?

27. What is leukemia?

28. What are deficiency diseases? How do they differ from infectious diseases?

29. Why is highly polished and good-to-look-at rice inferior to brown rice in food value?

30. What diseases develop due to lack of iron and iodine in our body?

31. Name the chief natural sources of vitamins A, B-group, C, D and E.

32. What is an allergy? Can you name some agents to which you or your friends are allergic?

33. Which are the two valuable drugs used by early man that are still popular today?

34. What is chemotherapy?

35. Who discovered sulpha drugs?

36. Which drugs prevent malaria?

37. What is an antiseptic? Why is it necessary to sterilize surgical instruments?

38. What is an antibiotic? Why are scientists still looking for new antibiotics although they are plentiful?

39. Name four important diseases against which penicillin is effective.

40. What are the other uses of antibiotics besides treatment of diseases?

41. What is the chief difference between sulpha drugs and antibiotics?

42. Name the scientists who introduced painless and safe surgery.

43. What are the uses to which X-rays are put?

44. Why is modern surgery usually safe and comparatively painless?

45. What are your main responsibilities in keeping the health of your neighbourhood?

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CHAPTER 58

Biology in Relation to Human Welfare

Having studied this book now for several months, you must doubtless be familiar with the many facets of the biological science and their relation to our daily life. Even at the risk of some repetition, however, we are concluding this book with such a chapter, because the ever multiplying inventions in rocketry and space travel seem sometimes to obscure the importance of biology in the mind of an average man.

Biological vs Physical Sciences

We do not belittle the heroic achievements of spacemen Gagarin and Glenn or the efforts of the engineers that have gone into the construction of space capsules and rocket vehicles. Nor do we belittle the physicists who invented the atomic bomb, the nuclear reactor, radio, television and radar. These inventions are no doubt the product of much thought, creative genius, talent, labour and money.

Unfortunately some of the research by physicists is motivated for possible military use rather than for the benefit of human life. In the final analysis, however, the billions of dollars, pounds or roubles that go into their research are also expended to save humanity, although only a small section of it and at the expense of the rest of it. It is clear, therefore, that for all men (politicians and military experts included) biology commands a supreme position. It is our anxiety to survive that governs our life.

Like physics and chemistry, biology too can be exploited to provide military advantage, e.g. by developing germ warfare. However, it is distasteful even to consider such a measure. Biologists have in the past contributed much to the peace and happiness of world directly and by means other than annihilation of their fellow-men, and can continue to do so in future.

The Population Explosion

At the root of all turmoil, unhappiness and war is the evil of expanding population. The Japanese entered the Second World War mainly to find additional land for their teeming population which could neither contain nor feed itself in its own country. This was also one of the reasons which led Germany to declare war with Russia, because she had an eye on the vast wheat fields of the Ukraine.

Unfortunately most people in the world are illiterate and are not even aware of the population problem. Much less do they realize its huge complexity. It has been estimated that in the Stone Age there were

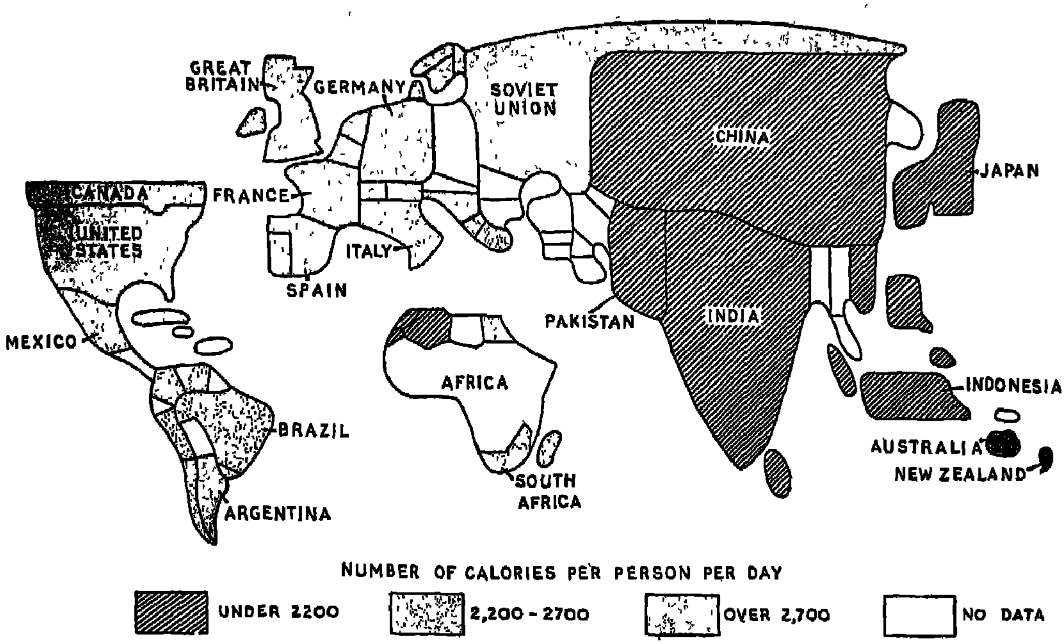

Fig. 58.1. In this map the sizes of the various countries have been shown in proportion to their populations. Compare this with a political map. Using the key at the bottom you can see the locations and sizes of populations which have the most severe shortages of calories in their diets. After A.O. Baker, L.H. Mills and J. Tanczos, Jr., *New Dynamic Biology*, Rand McNally & Co., Chicago, 1959.

only 10 million people. Around the year 4,000 B.C., when the Mahabharata war was fought, there were perhaps 100 million people; when Christ was born this figure rose to 200 million and when Babar became the first Mughal Emperor in India, it was 300 million. Today the total population of the world is 3,500 million. The number of men and women, therefore, is increasing fast; in fact much too fast and at the present annual rate of 1.8 per cent increase, the population is expected to be 5,000 million in the year 2,000. If you determine the number of brothers and sisters you and your class-mates have, you will probably arrive at a rough estimate that an average couple in India has about 4 children. Supposing that we start with 20 newly married couples, then after 15-20 years they with their children will number 120. Without going into detail we can see how the population can triple itself within a short period.

Every second about 3 new babies are being born, which means 180 new mouths to feed every minute! And while we have traced the growth of population for the last 8,000 years, we can hardly imagine the situation 600 years hence, since the population then will be 25 millions of millions with just about 5 square metres land for each person to stand on. This is a dizzying thought indeed and the only relief is that all of us will be dead then and the worry will be for our grand-children and great-grand-children.

The situation appears especially tragic when we consider the fact that the maximal rate of increase of population exists in those countries which are already the most

populous, e.g. India and China, where the people are ill-nourished (Fig. 58.1). Any material advance in our country is thus offset by the simultaneous increase in population.

Obviously, the population cannot be allowed to increase indefinitely. As biologists, we have a responsibility in educating our people about it. We first need to know whether the high rate of reproduction in certain countries is due to a higher rate of fertility. If this be so we should enquire into the causes and find methods to control fertility. Possibly the early marriages in oriental countries may also have some relation to this problem. Some research is being done in Europe and America to find a drug that would reduce fertility or prevent childbirth, but this needs to be stepped up very greatly. This is because in such work it is not so difficult to find a drug that cuts down fertility—in fact several effective drugs are known already—what is not known are the possible side-effects that these drugs may have on other functions of the human body. These investigations are painstaking and have to be continued for years to ensure that there are no ill effects. Such a tragic case occurred three years ago when the administration of the newly discovered drug thalidomide (then supposed to be the most harmless sleep-inducing drug) led to the birth of thousands of deformed babies to women who took thalidomide and who themselves showed no ill symptoms whatsoever.

The Food Problem

With the increasing population, we must simultaneously look into the ways and means by which we can augment the food supply of the world, and here comes the important role of the agriculturist, the botanist, the plant chemist, the zoologist and the geneticist.

As you have already seen in Chapter 39, a tremendous amount of effort has gone into the understanding of the mystery of photosynthesis. Until recently when man mixed carbon dioxide and water, the product was carbonic acid akin to soda-water. Today biologists can happily claim that sugar has been synthesized in the test tube from carbon dioxide and water but the amount synthesized is so small that even chemists need special training and techniques to detect it. The best we can say is we have just begun to understand the process and much further work will be needed before we learn to produce food ourselves cheaply. Research on photosynthesis need not be the monopoly of biologists alone. Even physicists can profitably undertake such investigations because the basic aim is to capture the energy of sunlight. If, instead of synthesizing sugar, this energy could be stored in a battery it would still be very useful to man.

Growing Healthier Crops

The pioneer studies of the two German botanists, Sachs and Knop, demonstrated that of all the elements necessary for a plant, only carbon and oxygen are obtained from the atmosphere. Molecular nitrogen, though abundant in the atmosphere, cannot be utilized by the majority of plants. It is out of their researches that modern agricultural practices such as adding fertilizers or rotation of crops to grow healthier plants have been born. Raising of the same crops such as rice continuously for thousands of years has, in some cases, impoverished our soils very much. Scientists are needed to cheaply and expeditiously diagnose the deficiencies of minerals in the soil and in the plant,to verify their diagnoses by small-scale treatment, and then to apply these measures to the entire field. Even though our country has an ancient heritage of agriculture, it is a pity that our yields are among the lowest in the world. In the United States of

America there are only 7 million farmers today in a population of 179 million. In other words, one American farmer is producing enough food for not only himself and 25 other men, but is able to export a considerable quantity. In India the majority of our population is engaged in farming; yet not only there is no surplus, but we import heavily to keep our people from starving. Indeed, we can double or even triple our grain production without clearing more of our forests provided we have the technical know-how. This can be provided only by soundly trained biologists and agriculturists.

New Sources of Food

Several botanists have studied the relative efficiency of utilization of light energy by different plants. It will surprise many of you to know that even the best crops under optimal conditions utilize only about two per cent of the solar energy that falls on them, the average being only 0.5 per cent. It seems that the low yields are primarily due to two reasons: (1) for most of the time the light which falls on the ground remains uncaptured by the plant, and (2) much of the organic matter produced is inedible. From this viewpoint, if algae like *Chlorella* could be cultivated on a large scale these might prove much better since they have no stem, root or bark where the food would be wasted. In fact, the entire alga can be used as food. Utilization of light in these organisms can reach an efficiency of as much as 20 per cent. Pilot-plant experiments conducted in the United States of America reveal that an acre of alga can produce as much as 40 tons of dry matter of which 20 tons is in the form of proteins alone. Such yields are inconceivable with any of our conventional crops.

Many technical difficulties such as the necessity of stirring the cultures, removal of heat due to sunlight, and the high cost involved in overcoming them prevent any immediate large scale switchover to such revolutionized farming. Moreover, this algal food may not be relished by people. However, many of us feel that the day is not far off when the present difficulties may be circumvented and we may be compelled to resort to algal farming and adapt our tastes to this new food.

Much research needs to be done also on the type of alga that would suit large scale cultivation. The blue-green algae such as *Anabaena* and *Nostoc* may prove still more useful in this regard because these can also fix nitrogen from the atmosphere.

Improving Our Livestock

India's cattle population is the largest in the world. What has been said about the inefficiency of our crop production, however, is also true of the livestock management in this country. A cow in the Netherlands, for example, produces about 10 kilograms of milk per day, but in India the average production is only a quarter of a kilogram. The problem is aggravated by religious sentiments since even a useless cow is allowed to live its entire tenure of life. Much work is needed by trained geneticists and breeders to improve their lot and to educate our farmers that it is better to do away with the useless cattle rather than torture millions of them by ill-nutrition and hunger.

Besides cattle, our poultry also needs to be improved. Scientific methods have also to be adopted to grow fish. It may be mentioned, however, that consumption of large quantities of non-vegetarian food, instead of vegetarian food, aggravates the food problem. Agriculturists contend that it requires about seven times as much land to grow food in the form of meat, eggs, milk and poultry as it does to grow grain and

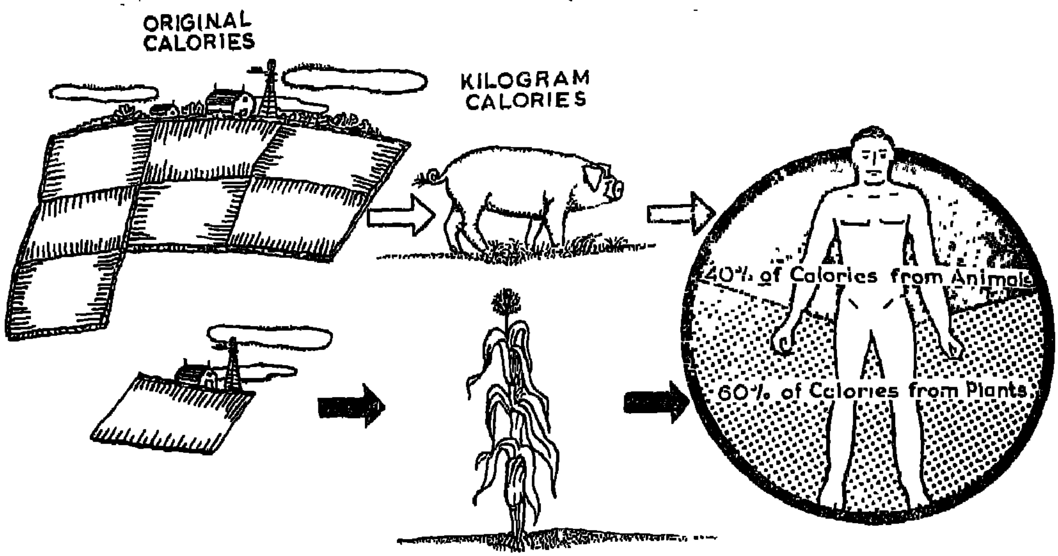

Fig. 58.2. In converting original calories into kilogram calories plants are about seven times more efficient than animals. Animal foods make up 40 per cent of the kilogram calories in the average person's daily diet. If the diet were to contain a greater percentage of kilogram calories from plants less land and fewer original calories would be needed to feed the population. After A.O. Baker, L.H. Mills and J. Tanczos, Jr., *New Dynamic Biology*, Rand McNally & Co., Chicago, 1959.

vegetable which contain the same number of calories (Fig. 58.2). If all people are willing to make adjustment, much land could be freed from the relatively inefficient production of livestock and poultry.

Conservation of Forests and other Natural Resources

You studied in Chapter 23, that the forests buried millions of years ago provide us with the coal that powers much of our industry, and gives us light and heat in our homes. The forests also give us timber for furniture and house-building, raw materials for the manufacture of paper and other products such as rubber, drugs (e.g. quinine), gums, resins, tar, pitch, turpentine and camphor. In some countries forest trees (e.g. maple) yield sugar.

Trees take in tremendous quantities of water during rains and so does the 'forest floor' with its tangle of roots and masses of decayed twigs and leaves. This prevents rivers from becoming unduly swollen and thus checks floods. The liberation of vast amounts of water vapour in summer also moderates hot weather. People hardly realize that without the forest cover, the rains would have washed down much of our soil into the sea. Already, for want of proper soil cover, millions of acres of our land are eroded and made useless (Fig. 58.3). With a forest cover or contour farming this land could be saved (Fig. 58.4).

Yet, forests have not only been cleared to make room for towns and cities, but the lure of easy money has also made man cut down forests ruthlessly and perhaps more rapidly than his needs dictate. Thus, these forests which are of inestimable value have almost disappeared from the face of the earth.

Some enlightened foresters in the West

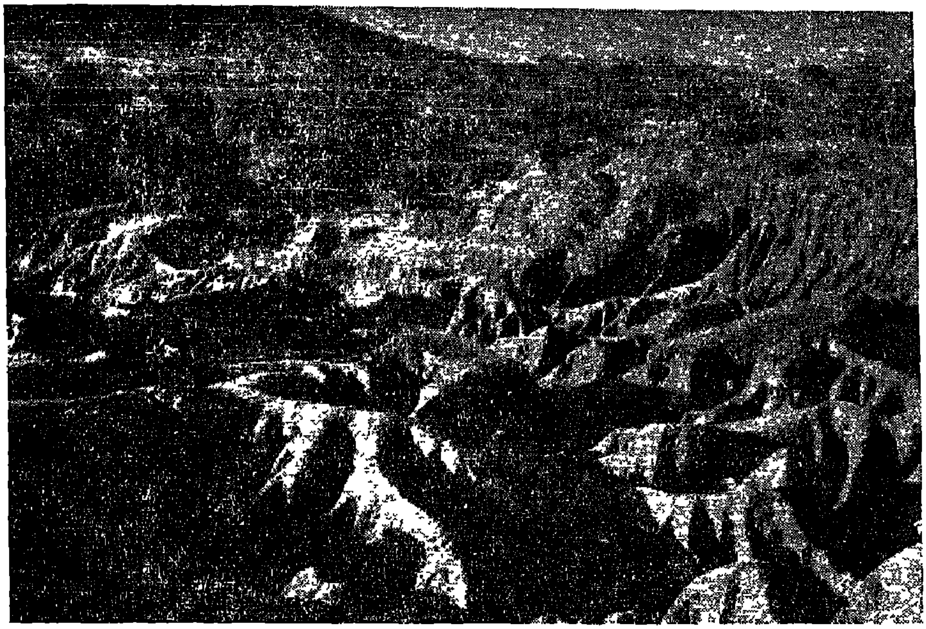

Fig. 58.3. Under unplanned deforestation and thoughtless removal of plant cover, the soil is easily washed away by rain or blown away by wind. The result is erosion. Courtesy of the Press Information Bureau, New Delhi.

Fig. 58.4. Soil erosion can be controlled by erecting bunds and by growing plants which are efficient soil binders. Courtesy of the Press Information Bureau, New Delhi.

voluntarily adopted a technique whereby in a few years' time the cut portion of a forest is replaced by a new crop. Since most individuals could not be expected to have the foresight to carry such a programme by themselves, Wilhelm Penn, Governor of Pennsylvania, USA, passed a decree in 1681 obligating owners of forests to leave one acre of forests for every 5 acres of land cleared. Today, most governments in the world, including our own, have forest departments to look after the problems of forests. Hundreds of young men employed by the Indian Forest Service are engaged in protecting and improving the nation's forest wealth. Extensive areas are being replanted with trees. Fire breaks, telephone systems, roads, and look-out stations are being constructed to aid the fighting of forest fires. Attempts are also being made to eliminate insect pests and fungal diseases.

Conservation of Flora and Fauna

The clearing of forests has naturally led to the extermination of species of plants and animals. Among these are birds, mammals, several conifers, ferns, etc. In our own country, tigers, maned lions and wild elephants are becoming extremely rare. In fact, zoologists estimate that one species of mammal is becoming extinct every year somewhere in the world. This is sad for all of us who love animals. Some of these are useful to man but, for many others, we are forfeiting even a chance to discover their possible use. In most countries, now-a-days, several wild areas have been designated as National Forests and National Parks. Here, hunting and similar activities that would interfere with animal life are banned.

Biology and Health

To live an active and fruitful life it is absolutely important that we remain healthy and free from the scourge of ill-nutrition and disease. This is a point that is particularly important for us in India where the average expectancy of life is only 41.2 years. We have about the maximum rates of death by cholera, pneumonia, typhoid, tuberculosis, smallpox, etc. One out of every four children is born dead. Because of ill-nutrition even the few years a man lives are wasted. It is no exaggeration to say that for the same number of man-hours, a Russian or a German accomplishes far more than an Indian.

Biology has a glorious chapter in this connection and some of the greatest contributions of science are in this area. One of these is the germ theory of disease. Although civilization dates back to 4,000 B.C., not until the eighteenth century did man know that most diseases are caused by micro-organisms. In Ireland when in 1844 a famine broke out due to destruction of the potato crop by *Phytophthora* (a fungus), all sorts of fanciful theories were propounded. According to one of these, the disease broke out due to smoke from the passing locomotives. Even when the downy mildew (*Phytophthora*) was discovered on the leaves, it took years to demonstrate that the mildew was not the consequence but the cause of the disease.

In the villages in our country, diseases like plague, malaria and cholera are still thought to be due to witch-craft, ghosts or due to the wrath of gods. Pasteur's work led to the hunt for disease-producing microbes and, in almost a century, the causal agents for typhoid, malaria, cholera and pneumonia were identified. The work of Koch on bacteria and of Lister on antiseptics followed immediately after. Sterilization of the operation theatre, bandages, instruments, etc., is a must in every hospital today.

Due to better sanitary precautions and higher standards of living, the incidence of infectious diseases has been greatly cut down. In technologically advanced countries of the

Fig. 58.5. Malaria is no longer considered to be caused by the 'wrath of gods' or by 'evil spirits'. A village school teacher is explaining to his students how mosquitoes spread malaria. Courtesy of the United Nations Office, New Delhi.

world, like the USA and Denmark, the average life expectancy is about 70 years and the modern man has reduced his death-rate to almost a third that of his ancestors.

The discovery of the antibiotics—penicillin, streptomycin, terramycin, chloromycetin, etc.,—is another outstanding achievement. These antibiotics are effective for almost the entire range of bacterial diseases and have cut down deaths due to septic wounds to a negligible value.

The idea of vaccination was also born out of Pasteur's work who used a vaccine prepared from affected dogs to control rabies. Later, Jenner made history by trying the smallpox vaccine on the eight-year-old boy, James Phipps (Fig. 57.4). Vaccination as a prevention against possible infection of tuberculosis, smallpox, diphtheria and cholera is a normal practice today (Fig. 58.6). We shudder to think what would have been our state without these discoveries by the biologists.

There are also the virus diseases of which common cold, measles, polio and cancer are the best examples. Salk made an outstanding contribution by developing a vaccine for polio which cut down death-rates to about 10 per cent on this account. Unfortunately no real cure is yet known for cancer and this is a challenge for you.

Sewage Disposal and Water Supply

In olden days, our wells and rivers were the only sources of supply of water, and washings from the domestic work just went in the backyard. The growth of towns and cities necessitated a centralized water supply and also the need for sewage disposal. Today we can have water any moment merely by turning the tap. However, the existence of such facility has also increased many times the threat of a city-wide contamination by a chance leakage or some other error. Such a mishap, in fact, occurred due to mixing of the sewage with filtered water supply in Delhi a few years ago, leading to a jaundice epidemic which affected nearly a third of the city's inhabitants. Successful discharge of these new responsibilities by the municipalities can be achieved only through employment of trained biologists who can regularly examine the microbial flora of filtered water supply, the degree of chlorina-

Fig. 58.6. Vaccination is an important medical practice to safeguard people against diseases. In this picture a doctor is shown injecting tuberculosis vaccine into the arm of a little girl. Courtesy of the United Nations Office, New Delhi.

Fig. 58.7. School students observing bottling of pasteurized milk in a pasteurization plant. Courtesy of the United Nations Office, New Delhi.

tion and any possible harmful effect on human beings.

Contamination of Food

Like water supply, the food supply is also important. In cities, such as Delhi and Calcutta, where thousands of tons of several commodities are consumed everyday, unscrupulous traders and innocent public may create a havoc. Almost all city councils today, therefore, employ food inspectors who must make regular visits to the food and vegetable markets of cities and report on the state of commodities sold. The government made a shocking revelation recently that some of the adulterants are being mass manufactured. To some extent such a state of affairs is owing to the lack of trained scientists who can chemically analyse the food, and check its effect on animals. An interesting example of the use of biological knowledge is in pasteurization of milk (Fig. 58.7) for which plants have been set up in Calcutta, Bombay and Delhi.

Improvement of Plants, Animals and Man

Mendel unlocked in 1866 the door to a very vast and economically important field

of biology, the science of genetics and breeding. Hybridization and selection for disease, drought or frost resistance, or increasedyield has become an usual routine for agriculturists. The yield of maize, cotton, sugarcane, wheat and rice, to mention only a few, have nearly doubled or trebled since these practices were adopted. Even entirely new crops have been created by man following hybridization. A good example is *Triticale*, grown in certain European countries, which combines the good gluten and bread-making quality of wheat (*Triticum*) with the hardiness of rye (*Secale*) to extreme cold.

Selection and hybridization in Nature must have gone on for millions of years and influenced the course of evolution. But man's awareness of these processes and the scientific exploitation of this knowledge is certainly recent.

Breeding is an unceasing challenge for geneticists because pathogenic bacteria, fungi and viruses are just as smart as ourselves. They can mutate (change) and multiply too, and newer varieties, more virulent than the earlier ones, are appearing almost constantly. Naturally, therefore, a variety found to be resistant today may not remain so tomorrow. This means we must toil hard, continue improving our stocks, and keep up the struggle. Among the various explorations of man in this regard is the use of atomic radiation for mutation and plant breeding programme (Fig. 58.8). Powerful gamma rays may, through induction of mutations, speed up work to a degree never imagined before.

Many people would like to see genetic principles also applied to the biological improvement of man himself and programmes for achieving this eugenic goal have already been formulated. The approach to eugenics is two-fold, negative and positive. The negative approach is to some extent being carried out already. For instance, if a mother is known to carry a serious disease that doctors know would be inherited by her children and lead to death, she may be sterilized. Positive eugenics would mean that we encourage intelligent men and women to produce more children and discourage the socially undesirable people to marry. However ideal it may seem, these things are much easier said than done. Too many social implications are involved in carrying out such measures and a good deal of research is needed to determine even the desirability of such a programme.

Biology and Atomic Radiation

Perhaps the most significant advance in the physical sciences during the twentieth century is the harnessing of atomic energy. Unfortunately, this energy locked up in bombs also poses the greatest hazard to mankind. The more powerful of these bombs can blast, within a few seconds, an entire city like New York, Moscow or Calcutta. Massive though their destructive capability is, the real horror of these bombs is not on this account but due to the permanent genetic damage caused to the survivors in the target area. This damage results from destructive invisible rays liberated after the explosion. Not only can we ourselves be crippled in such a war, but our woe and misery will pass down to our children, grandchildren and great-grand-children.

Nuclear energy, to a smaller extent, is also being employed for generating electric power, for driving submarines and surface ships. Nuclear-powered airships are already on the drawing boards of designers. The coal and petroleum resources are not infinite and efforts to harness atomic energy are, therefore, welcome. However, although all precautions are taken to ensure safety, accidents and mishaps are but natural and there is always a danger of radiation from reactor blow-ups. It is for the biologists to investigate the extent of this damage, to determine

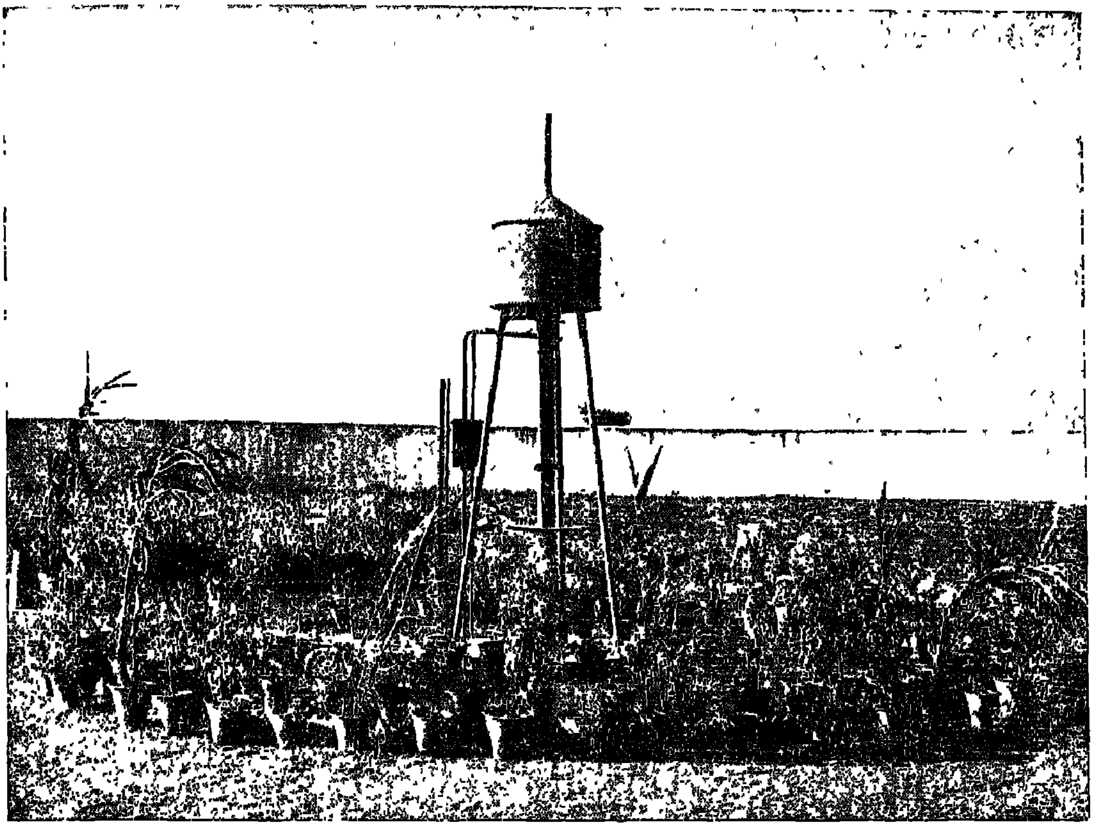

Fig. 58.8. New varieties of plants and animals can be produced by briefly exposing them to atomic radiations. The picture shows such an arrangement (Gamma Garden) at the Indian Agricultural Research Institute, New Delhi. Courtesy of M.S. Swaminathan, Indian Agricultural Research Institute, New Delhi.

their mechanism, and to find possible cures and remedies in case such exposure occurs. To focus attention on the dangers from radioactivity and to stimulate research, several universities in advanced countries are teaching special courses in radiation biology. It is clear that unless biologists contribute their part, it will be difficult to use nuclear energy on a large scale for peaceful purposes.

Biology in Relation to Space Travel

At present, space travel is primarily a military occupation and this research is conducted with strict secrecy. Some people think that satellites or rockets could be loaded with nuclear bombs, or may be spies, and either of these could be made to land on a predetermined target. It is conceivable, however, that in peace-time, these rockets and satellites could carry mail and material, along with mailmen or other passengers. Scientists could also travel in these satellites to investigate the nature of space and other planets. Jet aircrafts are in fact already being designed with speed exceeding that of sound by a factor of about 2 or 3. The only doubt that remains with regard to their future use is whether the human passengers, for whom these vehicles are designed, can stand the rigors of supersonic jet travel.

One of the serious problems that faces designers is the high force of gravity to which the passenger is subjected during take-off. Most of the blood tends to drain from the head during take-off, and collects towards the legs and the lower part of the abdomen, causing black-outs. Contrarily, during landing too much blood will tend to flow in the head (Fig. 58.9). Unless special arrangements are made, pilots during these critical times cannot be expected to intelligently control their vehicles. However, some relief is obtained if the pilot lies horizontally on his back during rapid acceleration, because in this position the blood will be more equitably distributed.

To avoid friction and burning up, the faster vehicles must fly very high. However, the atmosphere at high altitude is rarified and this is another problem for the future passengers. Not only is breathing difficult, but due to lowered pressure the blood may 'boil'. The cabins of these passengers are, therefore, pressurized and as a double precaution the fliers wear the pressure suits.

Many other factors, such as the effect of high temperature, natural radio-activity, jerks, etc., cannot be discussed here for want of space. Most of us are used to definite diurnal cycles of day and night, and for relatively infrequent long distance travel disturbance may not be too much. But man cannot very easily accustom to sudden and frequent changes of this cycle. Whether faster and frequent travel will be found feasible, cannot be predicted without biological studies of this kind.

Biology as a Fundamental Science

We have devoted almost all of the space, thus far, to the applications of biological knowledge to human welfare. Not for selfish motives alone, however, should we study plants and animals. Basically science is a quest for truth and although many persons are motivated to take up scientific work for the sake of its value to mankind, there are others who work regardless of its immediate relevance to human welfare.

Surprisingly, a great many of the science's most brilliant discoveries have come from men who undertook studies which at that moment could have no practical significance either in the investigator's own mind or in the minds of his colleagues. The discovery of plant hormones is one such example. Why do plants bend towards light was the question that struck Darwin's mind and he could have never conceived that the simple experiments with grass seedlings in his dark room would become the basis for the discovery of hormones and a revolution in modern agriculture. Similarly, the discovery of penicillin was a pure accident and not the result of any motivated investigation. Alexander Fleming was isolating some strains of a bacterium called *Streptococcus* and he was throwing away the petri dishes that were infected with other organisms. Only by chance did he notice a dish in which a green patch of fungus contaminant grew that had a strange halo around it. The bacteria around it had been killed by the excretion of some product from this fungus—*Penicillium*. This 'some product' later turned out to be penicillin.

You are aware of the microscopic world of bacteria and the great impact of this discovery on modern medicine. Yet, when Leeuwenhoek toiled and laboured to grind lenses and make a microscope, he could have hardly imagined the great potentialities his invention would have.

The invention of the dynamo by Faraday, and the discovery of radio-activity by Becquerel, are some of the examples in physics, where the inventors could have hardly conceived the tremendous medical

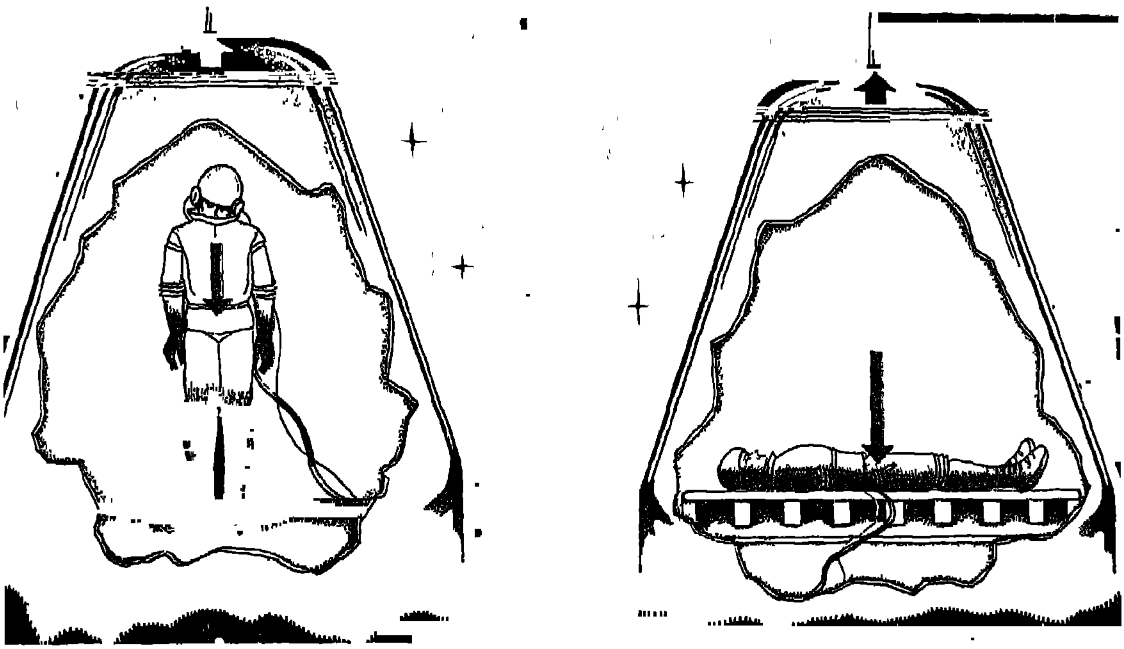

Fig. 58.9. The effects of rapid acceleration during take-off for space flight. Left. With the spaceman standing parallel to the direction of flight, blood drains quickly from the upper part of the body. Right. With the passenger lying at right angle to the direction of flight, blood is more evenly distributed, despite acceleration drag. From A.O. Baker, L.H. Mills, and J. Tanczos, Jr., *New Dynamic Biology*, Rand McNally and Company, Chicago, 1959.

and other applications that would follow. Examples can be multiplied further, but even the few that have been mentioned would adequately document the fact that discoveries in science mostly come unexpectedly, and to start one's work with an immediate reward in view is not necessarily the best way to serve science and humanity. The main requisite for an able scientist is curiosity and intelligence; he is best left to pursue his study as he desires. The public and the government can help by appreciating this fact and giving him all facilities needed.

One has merely to think to find challenging problems to step on to a scientific career. Why, for example, do the leaves of touch-me-not (*Mimosa pudica*) collapse when touched? No satisfying answer has yet been provided for this simple question. Similarly, there are other questions such as why do plants bend towards light? Why do leaves fall off? Why do they turn yellow and red in autumn? Why do we dream? How does a bat see his way in darkness? How do migratory birds find their direction and how are they able to fly non-stop for thousands of kilometres? Why don't we remain young always? You can ask yourself an infinite variety of questions, and contribute to the pool of knowledge in this world.

SUMMARY

Modern biology embraces a very wide area of science with many ramifications. You could specialize in virology, bacteriology, or microbiology, biophysics, biochemistry, embryology, physiologey genetics, psychology and a variety of other disciplines.

The three problems offering the biggest challenge to man are those of food, population and disease. These can be solved by introducing the new scientific methods of agriculture, abandoning the old ones, producing new and better yielding varieties of plants and controlling diseases and weeds. For example, many new varieties can be produced by causing mutations through atomic radiations; diseases can be controlled by finding new drugs, vaccines and antibiotics. Our country now needs many more biologists to enlighten the masses about the recent developments. Modern biology employs heavily the techniques of physics and chemistry. To be a good biologist of future, therefore, you must not only learn biology well, but also the essential principles of physics and chemistry.

QUESTIONS

1. In the last five decades, the human population has increased far more than in any of the past centuries. How can you explain the enormous increase?
2. Do you think increased literacy in future will help us to check the increase of population?
3. In what ways do the plant chemists and geneticists contribute to increase the production of food?
4. You may have heard of 'havanas' and 'yagyas' being performed in the villages to increase the yield of rice or any other crop. In view of the knowledge gained by you, do you think there is any scientific basis of such ceremonies?
5. Many of our farmers who are religious-minded are reluctant to practise the recent developments in agriculture. What remedy can you suggest to overcome this?
6. Mention some of the fruits and vegetables that have been introduced in India from other countries.
7. Our country has the largest number of cattle population in the world, yet the yield of milk is the lowest. Explain.
8. Mention ten economically important forest plants.
9. What will be the effect of removal of all forests in a sector of our country?
10. How do plants help in checking soil erosion?
11. What is the role of gardens, national forests, national parks and zoos in human welfare?
12. A few years ago when the supply of filtered water in Delhi was contaminated with sewage, the public was advised to drink water only after boiling. Why?

13. Name an animal and a plant that have been created solely by man's efforts through hybridization.

14. How can atomic nuclear radiations affect the future generations of man?

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